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Innervation of the Heart and Ductus Arteriosus and Other Features of the Autonomic Nervous System of the Full Term Human Fetus.

Frank D. Allan
Louisiana State University and Agricultural & Mechanical College

THE INNERVATION OF THE HEART AND DUCTUS ARTERIOSUS AND OTHER FEATURES OF THE AUTONOMIC NERVOUS SYSTEM OF THE FULL TERM HUMAN FETUS

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Frank Duane Allan
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LIST OF ABBREVIATIONS
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A.	artery
Ant.	anterior
Ao.	Aorta
Br.	large branch
br.	small branch
C.	cervical
Card.	Cardiac
Car.	Carotid
Cerv.	cervical
Collat.	collateral
Com.	common
Coron.	Coronary
D., D.A. or Duct.	Ductus arteriosus
Ext.	external
G.	ganglion
ICCSN	Inferior Cervical Sympathetic Cardiac Nerve
ICG	Inferior Cervical Ganglion
IGTsg	Interganglionic Trunk near superior cervical ganglion
IGT	Interganglionic Trunk
IGTamg	Interganglionic Trunk above middle cervical ganglion
In.	Innominate
Inf.	Inferior
Int.	Internal
Intermed.	Intermediate
Int. C. G.	Intermediate Cervical Ganglion
L.	left
Lat.	lateral
L. A.	Left Atrium or Auricle
LCCA	Left Common Carotid Artery
L. V.	Left Ventricle
Laryng.	Laryngeal
MCCSN	Middle Cervical Sympathetic Cardiac Nerve
MCG	Middle Cervical Ganglion
Mam.	Mammary
Med.	medial
Mid.	middle
N.	nerve
P or Plex.	plexus
Phren. N.	Phrenic nerve
Prox.	proximal
P. T.	Pulmonary Trunk
Pulm.	Pulmonary
R.	right

R.A.	Right Atrium or Auricle
R.V.	Right Ventricle
Rec. N.	Recurrent Nerve
Rt.	roots
SCCSN	Superior Cervical Sympathetic Cardiac Nerve
SCG	Superior Cervical Ganglion
Sl-X	Superior Laryngeal Nerve of the Vagus
Sp.	spinal
Stell.	Stellate
Sub.	Subclavian
Sup.	superior
Sup. Plex.	Superficial Cardiac Plexus
S.V.C.	Superior Vena Cava
Sym.	Sympathetic
T or Thor.	Thoracic
Thyr.	Thyroid
Thyrocerv.	Thyrocervical
Tr.	Trunk
Trans.	Transverse
Trans. S.	Transverse Sinus
V.	Vein
Vert.	Vertebra or Vertebral
X	Vagus nerve

ABSTRACT

Although studies of the autonomic nervous system of the cervicothoracic region in man have been numerous, certain features have escaped notation, whereas, others are in need of reexamination in order that a more accurate knowledge may be obtained. Furthermore, most previous work has been done on the adult, with few systematic studies existing regarding this system in the fetus. Thus, no detailed consideration of the origin and distribution of the extrinsic nerves to the ductus arteriosus has taken place.

The technics of this study were simple, but required tedious and delicate dissection of the neck and upper thorax of the full term fetus with detailed records, written and graphic, regarding the autonomic system in that area.

The study demonstrates that innervation of the ductus arteriosus is accomplished by the left inferior cervical sympathetic cardiac nerve by way of a plexus on the proximal part of the left subclavian artery, and by branches from the inferior cervical cardiac nerve of the vagus primarily as branches of the superficial cardiac plexus. The plexus upon the ductus distributes fibers to it and the pulmonary trunk, continuing to the left coronary plexus.

Sympathetic and vagal cardiac nerves are analyzed in regard to their frequency, origin, course, termination, communications, and association with accessory ganglia. These are largely confirmation of previous studies but present a more detailed knowledge of each,

and reconsiders features which have been lost from previous studies. Of the cervical cardiac sympathetic nerves, the superior occurs in 90%, whereas, the middle and inferior nerves are constant. Thoracic sympathetic cardiac nerves, usually 10 on each side, arise from the upper 6 thoracic ganglia and frequently form an accessory chain or plexus on the lateral aspects of the upper thoracic vertebra.

The intermediate cervical ganglion was found in 83% and is considered a usual component of the cervical chain.

Accessory ganglia are found in approximately 50% of the sympathetic cardiac nerves.

Of the vagal cardiac nerves, the inferior cervical are most constant although numerous branches are also observed from the thoracic portion of the vagus. The superior cervical, on the other hand, is rarely found per se.

Communications between cardiac nerves are constant and most frequently observed in the upper cervical region, less frequently in the lower cervical, and are absent in the thoracic region.

The cardiac plexus is classically divided into superficial and deep cardiac plexuses. The former is reanalyzed as to position, extent, and contributory nerves. It is divided into a preaortic, central, and preductal portions and receives branches from all the cardiac nerves on the left as well as a contribution of indeterminate origin from the right. The deep cardiac plexus was found to be essentially as previously described but certain refinements of that description with regard to its relationship to the pericardial sinuses and its communications with the superficial cardiac plexus have been added.

INTRODUCTION

The nerves to the heart have been the subject of numerous investigations during the past two centuries, but the information which has been gained still needs extension and clarification. The autonomic nerves and associated ganglia of the cervical and upper thoracic regions of full term human fetuses have been studied relatively infrequently, and no systematic study of the extrinsic nerves to the ductus arteriosus of the human fetus has been found in the literature.

The purpose of the present study is to describe the gross anatomical features of the extrinsic nerves to the heart and especially to the ductus arteriosus in the full term human fetus.

As an introduction to the problem, a broad review of published work will be presented including general features of cardiac innervation in addition to those which apply specifically to the present observations.

HISTORICAL

Comparative Anatomy

It is of interest that the first studies of cardiac innervation were made on man and that only during the last century and a half has much attention been given to lower forms. Comparative studies were eventually undertaken, however, in order to simplify or clarify the problem in man.

Although studies on mammals were made as early as 1815 by Weber, using the calf, the impetus which seems to have initiated these studies was the discovery and demonstration of the depressor nerve in the rabbit by Cyon and Ludwig (1867). This stimulated a series of papers concerning that nerve and led physiologists Gaskell and Gadow (1884) to undertake its study in reptiles and amphibians. His, Jr. (1891) included embryological studies in fishes as well as higher vertebrates. Schumacher ('02 a and b) made an extensive study of cardiac innervation from a comparative anatomical standpoint, especially on the depressor nerve of mammals. Mollard ('08) considered lower animals, including the invertebrates, in his work on the cardiac nerves, but apparently this was not the major part of his material. Perman's ('24) extensive work attempted to cover all aspects of the problem including comparative and embryological studies on mammals as well as man. A series of detailed studies of the cardiac nerves in several mammals and birds was made by Ssinelnikow ('28, bird), Anufriew ('28, cat), Schurawlew ('28, dog), and Wolhynski ('28, calf) from the same laboratory. Riegele ('26) presented a less complete work on the apes. Mention should also be made of studies by Shaner ('30) on the calf, Nonidez ('35, '39 and '41) on puppies, rabbits, cats and guinea pigs and Saccomanno ('43) on cats.

The studies referred to above and many others whose main purpose does not justify their citation here, have established a general plan for the cardiac nerves throughout the phylogenetic series. This plan begins in fishes (His, jr., 1890), with fibers to the heart derived exclusively from the vagus nerves, apparently limited to the venous mesocardium. In the amphibians (Gaskell and Gadow 1884) the sympathetic trunks contribute some fibers to the heart, but they join the vagus and are distributed with its branches.

In the reptiles (Gaskell and Gadow) the innervation of the heart is from both vagal and sympathetic sources, but the two sets of nerves usually follow separate paths to the heart. The vagal fibers pass along the great arterial trunks, whereas, those from the sympathetic reach the heart along the venae cavae. There is some indication that in snakes and lizards (Hirt, '21) the nerves from the two sources are fused. A ganglion in the vagus as it enters the thorax limits the origin of the cardiac nerves superiorly, and the sympathetic chain is enclosed in the intertransverse canal of the cervical region, thus limiting the uppermost origin of the sympathetic nerves to the heart.

An isolated but rather complete study of the cardiac nerves in birds by Ssinelnikow ('28) shows that these nerves present certain characteristics which resemble the reptiles. For example, a ganglion of the vagus at the superior aperture of the thorax, called the ganglion of Couvreuri, limits the superior origin of the cardiac nerves. In addition, the cervical sympathetic chain in birds is also enclosed in the canal of the intertransverse foramina and, therefore, the cardiac nerves are limited to an origin from the trunk prior to its entrance into the canal. Perhaps the most significant observations in the study are that the nerves arising from one side of the body supply the ipsilateral side of the heart, and that the anterior plexuses of the heart are mainly supplied with vagal fibers, whereas, sympathetic fibers from the upper three thoracic ganglia pass to the posterior plexuses.

As indicated previously, studies on the comparative anatomy of the cardiac nerves and associated structures have considered mammals more frequently than other forms, and certain papers provide a reasonably complete presentation of the cardiac nerves in this class.

The work of Schumacher ('02) reviews the pre-existing papers, and although its coverage of the mammalian series is quite complete, it loses some of its significance because of the small number of animals used in certain parts of the study. The depressor nerve is represented as including all nerves to the heart or great vessels from the vagus between the origins of the superior laryngeal (and sometimes from this nerve) and the recurrent nerves. The sympathetic cardiac nerves originate from the middle cervical down to the 6th thoracic ganglia, but those from the thoracic ganglia are found only in the Artiodactyla. The presence of a superior cardiac sympathetic nerve is limited to the apes and man. The depressor nerve ends in the wall of the aorta (and ductus arteriosus) and is designated, therefore, the aortic nerve of the vagus. Schumacher describes the sympathetic cardiac nerves as passing to the ventricles for the most part and, consequently, calls them the ventricular nerves; the nerves from the left side pass anterior to the great vessels and are usually more discrete than those from the right. He considers the cardiac nerves in mammals as supplying the ipsilateral side of the heart with an overlap where a portion of the left ventricle adjacent to the anterior longitudinal sulcus is supplied by fibers from the right side.

Perman's study ('24), which includes a representative number of mammals, is more complete but agrees in most parts with Schumacher's. According to Perman the depressor nerve, with roots of origin from the superior laryngeal nerve of the vagus, the vagus proper, and the sympathetic, exists only in cats and rabbits and more frequently in the latter. In other mammals this nerve is usually united with the vagus trunk or with the sympathetic. The presence of a common vago-sympathicus, i.e., a fusion between the cervical portion of the sympathetic trunk and the vagus, in the dog, calf, goat and sheep, usually results in the absence of a discrete depressor nerve in those animals. The sympathetic cardiac nerves consist of three or four nerves with origins from the middle cervical ganglion and the trunk above it, the ansa subclavia, and the stellate ganglion. As mentioned above, only the Primates, man and the macaque, have a superior cardiac nerve from the sympathetic. The Artiodactyla are the only animals observed to have thoracic cardiac nerves.

Perman divides the nerves to the heart into two groups, depending upon their relation to the transverse pericardial sinus. Nerves which arise at relatively higher levels pass ventral to the sinus, while those with origins at a lower level pass dorsal to it. The nerves passing ventral to the sinus follow the great arterial trunks, whereas those passing dorsal usually follow the remnants of the ducts of Cuvier to reach the heart. On the left, this pathway involves the pericardial fold of Marshall, a vestige of the reflection of the pericardium on the old duct of Cuvier. The nerves which follow the arterial trunks pass primarily to the anterior portions of the heart, whereas those with the ducts of Cuvier, pass to the posterior aspect. Perman, agreeing with Schumacher, notes both ipsi- and contralateral distribution of the nerves from a single side, although the contribution is greater from the left.

The most detailed accounts of cardiac innervation in an individual mammal are presented by Schurawlew ('28), Anufriew ('28), and Wolhynski ('28). These works agree with previous presentations, but modify and enlarge certain details.

The cardiac nerves of the dog (Schurawlew '28), distribute themselves to ipsi- and contralateral sides of the heart. Those nerves having a relatively high origin from the vagus or the sympathetic trunk pass anterior to the transverse pericardial sinus and eventually reach the anterior surface of the ventricles. Those with lower sources, i.e., at or below the superior aperture of the thorax, pass posterior to the sinus and extend to the posterior portions of the heart. A detailed description of the atrial plexuses and a similarly detailed mention of the nerves to the pressor receptor areas are the primary contributions of this work.

According to Anufriew ('28), as well as Schurawlew, the majority of fibers arising on the left side from the stellate ganglion or below reach the heart through the pericardial fold of Marshall and are distributed to the posterior cardiac plexus.

Certain characteristics of the cardiac nerves in the calf (Wolhynski, '28) are modified by the presence of a brachiocephalic artery (anterior aorta) but the general plan of the mammalian cardiac nerves is the same and thoracic cardiac nerves from the sympathetic trunk are present. These branches follow the left superior vena cava, which persists in the calf, in order to reach the posterior aspect of the heart.

The history of the thoracic sympathetic cardiac nerves has been reviewed by Mitchell ('49) who noted that they had been observed in the calf by Weber as early as 1815. Physiological studies by Cannon and associates ('26 a and b) provided the stimulus for the "rediscovery" of these nerves by Ionescu and Enaschescu ('27 and '28), and Braeucker ('27), although these nerves needed no "rediscovery" in an anatomical sense, since they appeared in papers by Schumacher ('02), Mollard ('08), and Perman ('24).

The studies of Nonidez ('35, '39, and '41) extend beyond the scope of this investigation but it should be mentioned they establish the location of the pressor receptor areas and determine the nerves which pass to them. This work was done with puppies, rabbits, guinea pigs, and cats. Careful analysis must be given to Nonidez's work because his nomenclature is different than that of previous investigators. For example, a superior cardiosympathetic nerve is described in dogs, whereas, other investigators state that no nerve homologous to the superior cardiac sympathetic nerve is present. Furthermore, this description is modified by the presence of a vagosympathetic fusion in the neck which limits the conclusions which can be drawn regarding branches from this region.

In summary, certain general trends of the comparative anatomy of the cardiac nerves may be outlined. In fishes the heart receives its nerve sypply from the vagus only. There is a rudimentary sympathetic system which lacks any apparent nervous connection with the heart. This situation prevails in amphibians also where the primary source of nerves to the heart is the vagus, although some nerves of sympathetic origin probably reach the heart.

In reptiles, the sympathetic trunk ganglia in the lower cervical and upper thoracic region give a definite contribution to the heart. In some reptiles the cervical sympathetic trunk enters the canal formed by the intertransverse foramina of the cervical vertebrae and is, therefore, buried deep in the cervical region.

In birds and mammals the autonomic nervous system and its subdivisions have reached their greatest development, probably in response to, or concommitant with, greater freedom from the environment. This necessitated the development of homeostatic mechanisms and their control through an integrating center. The circulatory system, being one of the chief homeostatic mechanisms, has come more and more under the influence of the sympathetic system with a consequent increase in the number and complexity of its nerves.

In birds the presence of the ganglion of Couvreuri on the vagus at its entrance into the thorax limits the exit of vagal cardiac nerves superiorly. The origin of sympathetic fibers is limited superiorly by the fact that the trunk is buried in the intertransverse canal of the cervical region. Vagal fibers arising from one side of the body reach and supply the ipsilateral side of the heart. Sympathetic fibers reach the heart along the great veins, whereas, the vagal cardiac fibers pass along the arteries or veins depending upon whether they arise from the vagus high or low in its course. Kuntz ('10) believes that the autonomic nervous system in birds followed a separate evolutionary trend, and any comparison of the system between birds and mammals ought to be qualified with that possibility in mind.

In mammals, members of the same order demonstrate the same characteristics of origin, course, and distribution of nerves to the heart. In the Carnivora, nerves from both sides of the body take part in the formation of the cardiac plexuses and are distributed to the same and opposite sides of the heart. However, the contribution of nerves from the left side are usually more numerous and pass anterior to the aortic arch. The postion and innervation of the pressor receptive areas have been quite well established inthis order.

More work has been done on cardiac innervation in rabbits than in any other mammalian form, except man. No basic differences have been shown from other mammals, however, except that the aortic depressor nerve is an entity.

In the Ungulata, a characteristic feature of the cardiac nerves is the presence of a well established group of nerves to the heart from the thoracic sympathetic trunk. Another feature, apparently limited to this order, is the occasional presence of a group of nerves which pass to the right of the aortic arch to reach the anterior surface of the heart.

Little work has been done on primates other than man, but from all indications the similarity which is to be noticed between members of the same order holds true here. The presence of cardiac sympathetic nerves from the upper four thoracic segments is a constant feature, and it appears that the superior sympathetic cardiac nerve is present only in this order.

Human Anatomy

Fallopius (1561) apparently was the first to investigate the nerves of the heart in detail. He recognized a plexus between the aorta and the pulmonary trunk with contributions from both sympathetic and vagus nerves. Prior to this, a single nerve to the heart was described by anatomists, including Vesalius.

During the next 100 years very little was added. Willis (1667) made a division of the plexus, but it remained for Senac (1749) to locate the divisions definitely. He describes the cardiac plexus as consisting of " le grande plexus anterieur" anterior to the aortic arch and " le grande plexus posterieur" located on the deep surface of the arch. This interpretation was substantiated by Haller (1757) and Andersch (1791).

Three plexuses were distinguished by Murray (1772), the first anterior to the aortic arch, the second between the aorta and (right?) pulmonary artery, and a third on the posterior wall of the heart. Wrisberg (1786) found a ganglion, which today bears his name, within the cardiac plexus below the arch of the aorta.

The work of Scarpa (1794) is of particular significance, because of the excellent drawings and the first detailed consideration of the origin and course of the cardiac nerves. Of particular interest to the present study are certain features of the extrinsic nerves of the cardiac plexus, such as the plexus on the proximal portion of the subclavian artery formed by nerves from the middle and inferior cervical ganglia, and the nerve from the inferior cervical ganglion on the right passing anterior to the aorta to reach the interval between the latter and the pulmonary trunk. Also, a large branch from the plexus in this interval loops anterior and to the left of the ligamentum arteriosum and then along the lateral aspect of the pulmonary trunk to the left coronary plexus. Finally, the vagal cardiac branches are limited in origin to, or below, the level at which the nerve crosses the subclavian artery. Mayer (1794), also described the superficial portion of the cardiac plexus as receiving the superior cardiac nerves of both sides.

During the first half of the 19th century not much significant work appeared. Usually the cardiac plexus was regarded as an entity divided into two portions, but some authorities looked upon it as having further subdivisions. Swan (1830) separated it into right and left lateral cardiac plexuses, which communicated with the cardiac nerves in the neck, the ventricular and atrial plexuses, and the right and left thoracic plexuses. His is the first description of the thoracic sympathetic cardiac nerves in man, but he was not aware of their significance.

Valentin (1841) divided the superficial cardiac plexus into two parts, one anterior to the aortic arch and extrapericardial, the other intrapericardial along the aorta and the pulmonary artery. The presence of a small ganglion on the superior cardiac nerve was also noted and called the " gangliacum cardiac superior s. minus".

Cruveilhier's (1845) description of the cardiac nerves is reminiscent of that by Murray cited above. The nerves are divided into three planes according to their relationship to the aorta. In one plane, the superior and middle cardiac nerves from the left side pass ventral to the aortic arch toward the right coronary plexus. The nerves from the right side pass dorsal to the aorta and join the two previously mentioned nerves in the concavity of the arch at which point the ganglion of Wrisberg is located. Cruveilhier associated the latter ganglion particularly with the nerves passing ventral to the aortic arch. The second plane of nerves passes from the deep surface of the aortic arch to the coronary plexus of both sides. The third plan of nerves passes dorsal to the aortic arch and is distributed to the atria and posterior surface of the heart.

The work of Ellis (1849) and to a lesser extent that of Swan, have been used as a basis for most descriptions of the cardiac nerves in textbooks of anatomy written in English. Ellis followed the lead of earlier investigators in describing two plexuses, a superficial and a deep. The former plexus, which is found between the arch of the aorta and the ligamentum arteriosum, receives the left superior cardiac nerve of the sympathetic and the lower cardiac nerve of the left vagus, as well as a considerable contribution from the deep cardiac plexus. With regard to the deep plexus, Ellis makes the classical statement that it receives all the cardiac nerves except those referred to above, i.e., the left superior cardiac nerve of the sympathetic and the lower cardiac nerve of the vagus. Nerves from the superficial cardiac plexus extend between the aorta and the pulmonary artery to the anterior coronary plexus, whereas those from the deep plexus, especially the left half, pass to the posterior coronary plexus. Confusion has arisen because Ellis refers to the right as the anterior coronary artery and to the left as the posterior coronary artery.

Sappey (1852) holds much the same position in the French school of anatomists. He identifies the cardiac plexus as the communications of cardiac nerves from the vagus and sympathetic in a space limited to the right and above by the angle of the aortic arch, on the left by the ligamentum arteriosum, inferiorly by the right pulmonary artery, and posteriorly by the tracheal bifurcation. In the center is the ganglion of Wrisberg, which may consist of several rather than a single ganglion. Inferiorly the plexus divides into three portions; an anterior, between and superficial to the aorta and pulmonary trunk, continuing as the right coronary plexus; a middle, anterior to the right pulmonary artery in the interval between the pulmonary trunk and the aorta; and a posterior, behind the right pulmonary artery, the pulmonary trunk and the auricle. The anterior portion of the plexus receives branches from the cardiac nerves on the left. Thoracic cardiac branches are described, but their contribution is small.

Sappey recognizes the communications between the superior laryngeal nerve of the vagus and the superior cardiac nerve. The cardiac nerves of the vagus are divided into superior, middle, and inferior groups, the first two representing the cervical and the last the thoracic branches.

Henle (1871) established a plan of cardiac innervation, agreeing with the earlier data which was used by many German texts. He described a superficial and a deep cardiac plexus, and fibers from the latter which reached the atria. He included the ganglion of Wrisberg in the superficial plexus.

His, Jr. (1891), in describing the development of the cardiac nerves, gives three plexuses, an arterial plexus, an atrial plexus, and a plexus of nerves uniting the two. Gegenbauer ('03) applied His' designations, with slight modifications, to the adult. Both of the latter interpretations resemble those of Cruveilhier cited above.

Schumacher ('02) states that the cardiac plexuses can be divided logically into superficial and deep portions, with boundaries essentially the same as those described above. He indicates, however, that these plexuses constitute a " Grenzstein" or boundary for studies on the innervation of the heart. He considered the ganglion of Wrisberg as a point to which all the cardiac nerves converge. He also recognized a small nerve from the right passing to the superficial cardiac plexus.

Jacques (' 02) presented essentially the same picture as that of Sappey, indicating that all of the cardiac nerves on the left contribute branches to the superficial cardiac plexus.

The next articles of significance to this study are by Worobiew (' 17 and ' 26). The nerves intimately associated with the heart are divided into six plexuses according to the portion of the heart which they innervate. Although these plexuses may be classed as independent cardiac plexuses, they are actually extensions of the classically described superficial and deep cardiac plexuses. The divisions are outlined as follows: I. Left anterior longitudinal plexus, located on the left ventricle, extends from the atrioventricular sulcus to the apex of the heart. II. Right anterior logitudinal plexus, on the right ventricle. III. Right posterior longitudinal plexus, includes fibers innervating the right atrium (especially the sinus venosus), the posterior portion of the right ventricle, and the inferior and lateral aspect of the left ventricle at the apex. IV. Left posterior longitudinal plexus, encompasses the left atrium and ventricle adjacent to the sulcus. V. Anterior atrial plexus, includes nerves on the pulmonary veins and radiates over the anterior surface of the atria. VI. Posterior atrial plexus, includes nerves on the pulmonary veins at their entrance to the left atrium (Haller's plexus).

Jonnesco ('23), in a monograph on the cervical and thoracic portions of the sympathetic system, suggests that the cardiac nerves be numbered, since not infrequently one of them is lacking. He indicates that the ganglion of Wrisberg is in the center of the cardiac plexus and that the latter is separated into three planes, superficial, middle, and deep, for terminal distribution.

Perman ('24) was the last investigator to undertake a really comprehensive study of the cardiac nerves in man. In this study, which includes comparative and embryological observations as well as an extensive review of the literature, Perman concludes that a uniform picture of the cardiac nerves cannot be obtained from reports in the literature, not only because of the differences in the observations of various investigators, but also because of misinterpretations of the material presented. He points out that the cardiac plexus need not be considered the " Grenzstein" (Schumacher, '02) for investigation of the innervation of the heart. He traces nerves from both sides of the body to the heart with some degree of accuracy, showing that both sides of the heart may receive nerves from the same and opposite sides of the body.

Perman emphasizes the relation of the nerves to the transverse pericardial sinus in determining the portion of the heart they eventually reach. Thus, the nerves passing along the great arteries ventral to the sinus go to the coronary plexuses, whereas, those which pass with the great veins, or the remnants thereof, go to the atria and posterior aspect of the heart. This is an expression in the adult of the concept of His, Jr., cited above, regarding passage of nerves through the arterial and venous mesocardia of the embryo. Perman noted that occasionally the left middle cardiac nerve passes ventral to the aortic arch and in one instance he observed that all the cardiac nerves on the left joined and passed ventral to that vessel. Sometimes the superior cardiac nerve on the left passes dorsal to the arch, while all others on that side go ventral to it and enter the superficial cardiac plexus. He also observed that an occasional small branch from the right reaches the latter plexus. A branch from the plexus sometimes crosses laterally over the ductus Botali (ductus arteriosus) and reaches the left pulmonary plexus. Nerves from the same plexus, in the interval between the aortic arch and pulmonary trunk, contribute fibers to the ductus Botali as well as to the pulmonary artery.

Of the nerves which pass to the deep cardiac plexus, Perman noted that those on the left supply fibers to the ductus Botali and the pulmonary trunk, and one of the branches extends to the heart by transversing the pericardial fold of Marshall. The majority of the nerves on the right pass ventral to the right pulmonary artery, between the pulmonary trunk and the aorta, to reach the right coronary

Ionescu and Enaschescu ('27 a) established the presence of these nerves arising as low as the 5th thoracic ganglion in human full term fetuses. The nerves were found bilaterally in 7 of 10 specimens examined and unilaterally in the others, with only one or two nerves observed on each side, and the most common source being the third thoracic ganglion. The nerves passed to the heart either directly or by way of the aortic plexus. Braeucker ('27) gave less information, but indicated that the contribution was by way of the mediastinal branches of the upper 4 or 5 thoracic ganglia, entering, for the most part, the deep cardiac plexus. Communications with the inferior cervical cardiac nerves were also noted.

Kuntz and Morehouse ('30), using fetal and adult human material, concluded that the nerves which arise from the 2nd, 3rd, and 4th thoracic ganglia pass to either the deep or the superficial cardiac plexuses. According to Saccomanno ('43), in cats and man the superior cervical cardiac nerve passes posterior to the aortic arch, whereas, the middle and inferior nerves usually pass anterior to it. He noted that these nerves become materially reduced in size as they traverse the neck and attributes the loss to branches given off to visceral structures. The thoracic sympathetic cardiac nerves pass from the 3rd, 4th, and 5th ganglia, numbering 15 to 20 on each side with a total cross sectional area about twice that of the cervical cardiac nerves.

plexus.

Hovelacque ('27) presented a complete summary of the extrinsic nerves of the heart, describing in detail the inferior sympathetic cardiac nerve and the 4th cardiac nerve, the latter noted as often crossing anterior to the aorta on the left side.

More recently, Arnulf ('39, '49 and '50) has described the nerves passing anterior to the aortic arch as belonging to a preaortic plexus. The nerves are usually 5 in number, two from the left vagus in the neck, one from the superior cervical and two from the stellate ganglia on the same side. A portion of this plexus continues upon the ascending aorta, whereas, the remainder joins the " precardiaque" plexus, and with fibers from the latter, forms " le nerf principal du coeur" , which descends on the anterior surface of the pulmonary trunk. These observations have been substantiated by Hantz ('51).

Prior to 1920, cardiac nerves arising from the thoracic portion of the sympathetic chain had been described in the Artiodactyla (Weber, 1815, Schumacher, '02) and in man by Swan (1830). Valentin (1841) made brief notations on these nerves, especially the highest, but most investigators considered the first thoracic ganglion as the lowermost boundary for origin of cardiac nerves. Physiological studies by Cannon and associates ('26) led to a series of anatomical investigations of the thoracic cardiac nerves.

The demonstration of vagal inhibition of the heart by Webers (1845) and the demonstration of a depressor nerve by Cyon and Ludwig (1867) in rabbits, caused an increased interest in the anatomy of the vagal cardiac nerves in man. Finklestein (1880) describes a depressor nerve from the vagus high in the neck in two of five human specimens. Alpiger (1890), on the other hand, considered communications between the vagus and the superior cardiac nerve of the sympathetic to be the proper depressor nerve.

Schumacher ('02) considers this nerve in man to be represented by the upper cardiac branches of the vagus and the cardiac branch of the superior laryngeal nerve. Perman ('24) agreed with these findings, but emphasized that the communications between the latter and the superior (cervical ?) cardiac nerve presumably correspond to the depressor nerve. Jonnesco and Ionescu ('26) reported an isolated depressor nerve in a patient undergoing sympathectomy, which caused the classical response when stimulated. In the same paper, one of the authors (Jonnesco) observed that he had found this nerve in man in 50% of the cases examined.

The depressor nerve was also studied by Duncan ('29) who concluded that its existence as an isolated nerve, i.e., the superior cardiac ramus of the vagus, is not tenable, and that fibers representing this nerve have widespread origin and vary greatly in size.

Ductus Arteriosus

A paucity of information exists regarding the source of the nerves to the ductus arteriosus, their course, relationships and the manner in which they reach their destination.

The presence of nerve fibers in the wall of the ductus arteriosus, which can be demonstrated histologically, has been reported and described by numerous investigators; Tello ('24), Nonidez ('35, '37), Boyd ('37, '41), Muratori ('37), Watanabe ('38), Takino and Watanabe ('38), Kennedy and Clark ('41), Hammond ('41) and more recently, Noback and Anderson ('52).

In contrast to this formidable series of investigations, those which have attempted to present the gross anatomy of the innervation are rare. Lomakina ('00) briefly noted nerves passing to the ductus Botali of the horse, and although the accompanying illustration shows a plexus of considerable size on that vessel, the origin of its nerves cannot be observed in the illustration nor determined from the text. In studies which have included mice, rabbits, cats, and guinea pigs, Tello ('24), Boyd ('37, '41), Nonidez ('35, '37), and Hammond ('41) concur in the observation that the ductus arteriosus receives fibers from the left aortic depressor nerve. In all of these papers, save those by Boyd, the descriptions are very brief statements that the aortic depressor sends fibers to the ductus. Boyd is more explicit and states that in embryonic and fetal rabbits nerves can be traced from the aortic depressor beyond its normal area of distribution (the aortic pressor receptor area), to the ductus arteriosus at its junction with the aorta. Other branches leave the aortic depressor nerve proximal to those to the pressor receptor area and pass to the ductus at a point some distance from its junction with the aorta. As the vagus crosses the ductus it supplies fibers to the anterior and inferior surfaces of that vessel, whereas, the branches mentioned above pass to the superior and posterior aspects. In a few specimens the left recurrent nerve was observed to send a few branches to the ductus.

Boyd also observed that the aortic nerve was a branch of the vagus which included fibers from the lower cervical sympathetic trunk. He further states that some sympathetic fibers reach the ductus arteriosus from the lower cervical and upper thoracic portions of the sympathetic cord, but admits that the serial sections used in this study as well as the ...." experimental results on adult rabbits made no contribution to this aspect of the problem, the relationship of the sympathetic fibers to the ductus is left undecided by the material available."

Boyd ('41) cited a concept held by Koch ('31) that derivatives of the primitive aortic arches have specialized pressor receptors in them. The vagal branches to the ductus arteriosus, a remnant of the primitive sixth aortic arch, may very well fit into this category.

References to the nerves which supply the ductus arteriosus of man are rare and incomplete. The first contribution to the literature was made by Schumacher ('02) who observed that branches of the aortic depressor nerve of mammals, including man, reach the ductus arteriosus. Perman ('24) states that nerves running ventral to the aorta yield some branches to the ductus Botali. Boyd ('41) concluded that the innervation of the ductus in other types of animals (including man) is similar to that described in the rabbit.

Kennedy and Clark ('41, '42) studied the ductus arteriosus in the guinea pig from anatomical and physiological aspects. Presence of nervous tissue in the wall of the ductus was affirmed and, as in earlier investigations, nervous elements with apparently both sensory and motor functions were described. The latter type of nerve appeared less frequently compared with the sensory elements. On the physiological side ('42), doubt was cast on the necessity of a nervous reflex mechanism mediating closure of the ductus arteriosus. Extirpation of possible sources of nerve fibers to the ductus arteriosus was undertaken, and included the vagi, stellate ganglia and portions of the spinal cord, with apparently little or no effect upon the closure of the ductus. This seemed to indicate that closure of the structure may be independent of nervous control. Electrical stimulation of the same structures, i.e., the vagi and stellate ganglia, could not be correlated with closure of the ductus.

In contrast to the findings just presented, Barcroft, Kennedy and Mason ('38) reported blanching and constriction of the ductus arteriosus when the peripheral end of the cut vagus was electrically stimulated. The study of Kennedy and Clark however, gives evidence of being better controlled. Barclay and associates ('45), in their monograph on fetal circulation, have summarized the existing knowledge regarding the innervation of the ductus arteriosus in the statement, " It (the ductus) has some innervation, but the full details are not available, ... " .

Intermediate Cervical Ganglion

Jonnesco ('24) was the first investigator to name the small ganglionic swelling of the cervical sympathetic trunk frequently found just above the inferior cervical ganglion in intimate relationship with the anterior and medial surface of the vertebral artery. The intermediate cervical ganglion, as it was so named, is also closely associated with the inferior and medial surface of the inferior thyroid artery. It is linked with the inferior cervical ganglion by two trunks which embrace the vertebral artery, one passing anterior and one posterior. This ganglion is joined to the 6th and 7th cervical spinal nerves and gives branches to the subclavian artery.

Hovelacque ('27) observed this structure and agrees to its designation as the intermediate cervical ganglion. Lazorthes and Cassan ('39) observed the integrity with constant occurence of the ganglion and believe that it should be considered with the inferior cervical and 1st thoracic as the cervicothoracic ganglion. The latter investigators emphasized the fact that the interganglionic trunk splits to enfold the artery and constitutes the " ansae vertebrales" . They also indicated that the constancy of the origin of the ansa subclavia from this ganglion.

Axford ('28), on the other hand, concludes that all ganglia of the cervical trunk between the relatively constant superior and inferior ganglia should be considered portions of the middle cervical ganglion. He further states that the middle cervical ganglion can be classed as either a high or low type relative to its position. The low type of the middle cervical ganglion of Axford corresponds, in most particulars, with the intermediate ganglion of Jonnesco. Axford based his conclusion on the rami communicantes of the ganglion to the 5th and 6th cervical spinal nerves, noting, however, that they sometimes included the 7th.

Matsui ('25 a), studying the cervical sympathetic chain in human new born, indicated that as many as five ganglia may exist between the superior and inferior cervical ganglia. The average number of the ganglia was slightly over two, and their usual position was either opposite the 6th cervical vertebra, the high type of Axford (in 41%), or opposite the 7th cervical vertebra (in 50.6%).

Kirgis and Kuntz ('42) indicate that the intermediate cervical ganglion seometimes receives a white ramus communicans from the 8th cervical spinal nerve when the thoracolumbar outflow is prefixed.

Saccamonno ('43) states that the intermediate cervical ganglion was present in all cases examined, but that the middle cervical ganglion was often lacking.

Pick and Sheehan ('46) described the middle cervical ganglion, using the method of Axford, and observed the upper type ganglion in about 70% of the cases, regardless of presence or absence of the low type, whereas the latter was noted in 38%. The lower ganglion usually communicated with the 6th cervical spinal nerve and sometimes with the 7th.

Recently Jamieson, Smith and Anson ('52) have agreed with Axford, and observed that the middle cervical ganglion was present in 53% of 100 sides dissected, about equally divided between the high and low types. Vascular relations were noted in one-fifth of the dissections, and a middle cervical ganglion of the low type was observed anterior to the vertebral artery.

In the treatises on the autonomic nervous system by Mitchell ('53) and Kuntz (4th edition, '53) the intermediate cervical ganglion is described as a normal component of the cervical sympathetic trunk. The former author prefers, however, to designate this ganglion as the vertebral ganglion and to reserve the term intermediate for inconstant ganglia found on the rami communicantes (see also Wrete, '35 and '41).

Fetal Studies

In the preceding historical survey, most of the human material had to do with the adult. Schumacher ('02) conducted some of his investigations on the human fetus, although no distinction was drawn between fetus and adult. Braeucker ('23), in describing the nerves to the thyroid and thymus of a 7 month fetus, gave origins and relationships of the cervical cardiac nerves which agree with descriptions of these structures in the current literature. Perman ('24), in his much-cited work, conducted some observations on fetuses (25 full term), but incorporated them into the general body of the work and differences from the adult were not mentioned.

Matsui ('25 a and b) made a detailed study of the cervical and thoracic sympathetic trunks in the fetus, but did not consider their branches. It was pointed out that these structures appeared more primitive in the newborn (or late fetus) than in the adult.

Kondratjew ('26) used fetuses and children under two years of age for observation of accessory nervous structures, essentially sympathetic, in the thorax. Of greatest interest is the description of a collateral sympathetic trunk in the upper thoracic region found in one-third of the cases examined. This trunk begins in a small ganglion, the ganglion supremum, which lies posterior to the subclavian artery, is part of the subclavian or suprapleural plexus, and receives branches from the inferior and first thoracic ganglia and the ansa subclavia. It sends one large branch inferiorly along the anterior surface of the subclavian artery to the origin of that vessel and thence to the anterior aortic plexus. The remainder of the collateral trunk is formed into a chain by a series of four or five small ganglia, apparently the upper six thoracic ganglia. Inferiorly the chain is continuous with the greater splanchnic nerve. Its branches extend to mediastinal structures, i.e., cardiac, pulmonary, and esophageal plexuses.

Ionescu and Enachescu ('27 and '28) dissected 10 fetuses in a study of the thoracic cardiac sympathetic nerves and expressed the opinion that fetuses were preferable for this dissection because the plexuses were less well developed than in the adult. Kuntz and Morehouse ('30) also utilized full term fetuses for essentially the same reasons, in their study of the same nerves. The results of these studies have been presented elsewhere in this dissertation.

Siwe ('31), Botar ('32), Pick and Sheehan ('46), and Naatanen ('47) have utilized fetuses in studies on the autonomic system and, in so far as their work applies to the present study, they have been presented above.

III MATERIAL AND METHODS

Full term fetuses, obtained from the Pathology Department of Charity Hospital of Louisiana at New Orleans, were embalmed with a mixture of formaldehyde, glycerine, phenol and water through one of the umbilical arteries or through a femoral artery. Twenty-four hours of infiltration by gravity usually penetrated the tissues completely and gave good fixation. If an area was not well fixed at the end of the infiltration period, additional fluid was injected directly into that area with a hypodermic syringe. Between the period of embalming and that of dissection the specimens were kept immersed in a light-weight paraffin oil to prevent dehydration, in most instances, at least 6 months.

The fetuses used in the study were selected using size, apparent age, and nutritional state as primary criteria. Specimens which showed signs of venous congestion in the area to be dissected, made evidence by discoloration, were not used.

The specimens used were negroes with the exception of two (numbers 7 and 10) which were caucasian.

During and after dissection, a fetus was wrapped in cloths and kept moist at all times with a solution consisting of 2% phenol in water.

The first dissection entailed a thorough study of the cervicothoracic region from the base of the skull to the diaphragm and including all structures from the most superficial to the deep. Constant reference was made to a mounted skeleton of a full term fetus. During this dissection the technic necessary to preserve the delicate structures under consideration was developed and differences between fetal and adult anatomy were recorded. A series of 12 drawings of this dissection and detailed notations regarding all features of interest to this study were made.

Dissection was accomplished under a lens which provided magnification of two to three diameters, and instruments used in the dissections were as follows:

Scalpel - Bard-Parker #4 handle, " 10 and #11
Blades

Forceps - fine tipped and rat toothed

Scissors - fine straight, medium curved, large
curved

Chisel

Syringe - 20 cc with various sizes of needles

In all dissections except the first, as described above, the skin incisions were (a) a midline incision from the tip of the mandible to the xiphoid process, (b) a transverse incision along the lower border of the mandible, extending to the ear posteriorly, (c) a transverse one from the sternoclavicular articulation laterally to the tip of the acromion, then distally along the lateral aspect of the arm, (d) a transverse incision midway between b and c extending to the posterior border of the sternocleidomastoideus, (e) an incision along the lower border of the costal arch. The skin flaps, thus formed, the pectoral muscles and the clavicle were reflected laterally. The insertion of the Scalenus anterior was identified, this muscle reflected and the first rib bisected at that point. The ribs were severed along the mid-axillary line to the eighth or ninth rib and the whole anterior thoracic wall was then lifted and turned downward. The thymus gland was removed, thus clearing the area for further dissection.

In order to gain enough space to observe and dissect the structures at the base of the skull, i.e., the superior cervical sympathetic ganglion and its branches and the nodose ganglion of the vagus and its branches, the connective tissue, submaxillary gland and muscles superficial to the internal carotid artery were removed. The last mentioned structure was " stripped" and sectioned at its entrance to the skull. Frequently it was necessary to sever the branches of the external carotid artery and when this was done, the corresponding nervous plexuses were preserved by severing the arteries as far distally as possible.

For the first five dissections, notes were made regarding each and a mimeographed " basic" drawing was completed of the structures important to this study (Figs 1, 2, 6 and 7). A separate semidiagrammatic drawing was made for each of the sympathetic trunks and each of the vagi, their ganglia and branches. In all later dissections a summarized form of record was employed in which the desired information was arranged in a form convenient for analysis. The semidiagrammatic drawings of each dissections were continued.

OBSERVATIONS

Sympathetic Trunk

A brief summary of the major features of the sympathetic trunk of the fetus will be presented first to serve as a useful background for later descriptions. In addition, the intermediate cervical ganglion will be considered in more detail because of its controversial significance.

The sympathetic trunk was found to be completely developed and relatively large (Figs. 1 and 2). In the cervical region the trunk contained an average of 4 ganglia, with a variation of from 3 to 6. The superior and inferior cervical ganglia were the most constant with regard to size, shape, position, and occurence. The inferior was frequently fused with the 1st thoracic ganglion in which case it is termed the stellate ganglion. Between the superior and inferior ganglia, the cervical trunk contained two additional ganglia, the middle and intermediate. Each of the latter ganglia was occasionally divided into two or three independent enlargements.

The superior cervical sympathetic ganglion, oval or fusiform in shape, was constantly found, and extended from the base of the skull to a point approximately opposite the 2nd cervical vertebra (Figs. 1 and 2). It was intimately associated on its lateral side with the vagus nerve or the nodose ganglion. It had communications with the upper 3 or 4 cervical spinal nerves, and sent branches along both the internal and external carotid arteries, forming the

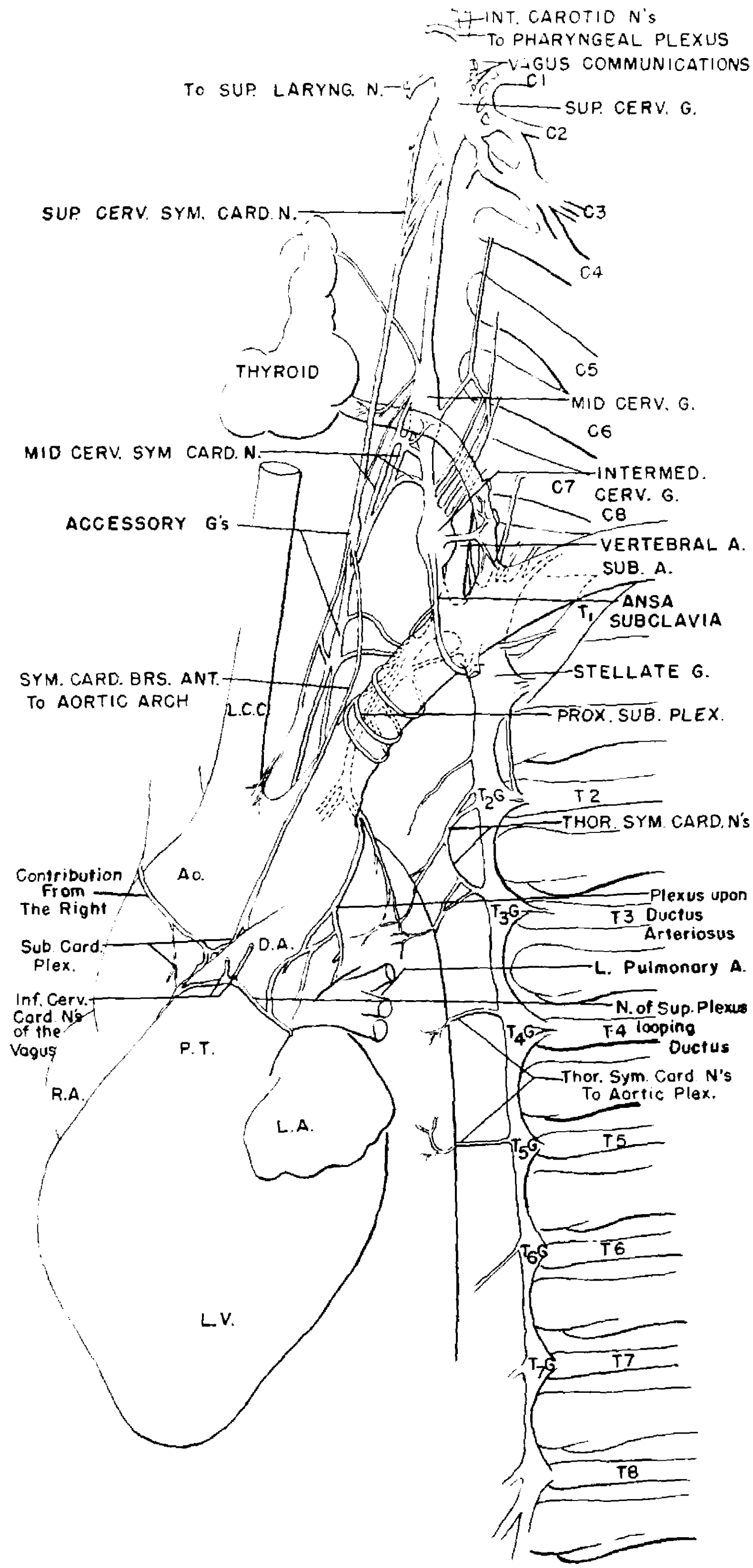

INT. CAROTID N's
To PHARYNGEAL PLEXUS
VAGUS COMMUNICATIONS
To SUP. LARYNG. N.
C1
SUP. CERV. G.
C2
SUP. CERV. SYM. CARD. N.
C3
C4
THYROID
C5
MID CERV. G.
C6
MID CERV. SYM CARD. N.
INTERMED. CERV. G.
C7
C8
ACCESSORY G's
VERTEBRAL A.
SUB. A.
ANSA SUBCLAVIA
T1
STELLATE G.
SYM. CARD. BRS. ANT. To AORTIC ARCH
L.C.C.
PROX. SUB. PLEX.
T2G
T2
THOR. SYM. CARD. N's
Contribution From The Right
Ao.
Plexus upon Ductus Arteriosus
T3G
T3
Sub Card. Plex.
D.A.
L. Pulmonary A.
Inf. Cerv. Card. N's of the Vagus
N. of Sup. Plexus looping Ductus
T4G
T4
P.T.
Thor. Sym. Card N's To Aortic Plex.
R.A.
L.A.
T5G
T5
T6G
T6
L.V.
T7G
T7
T8

Figure 1.

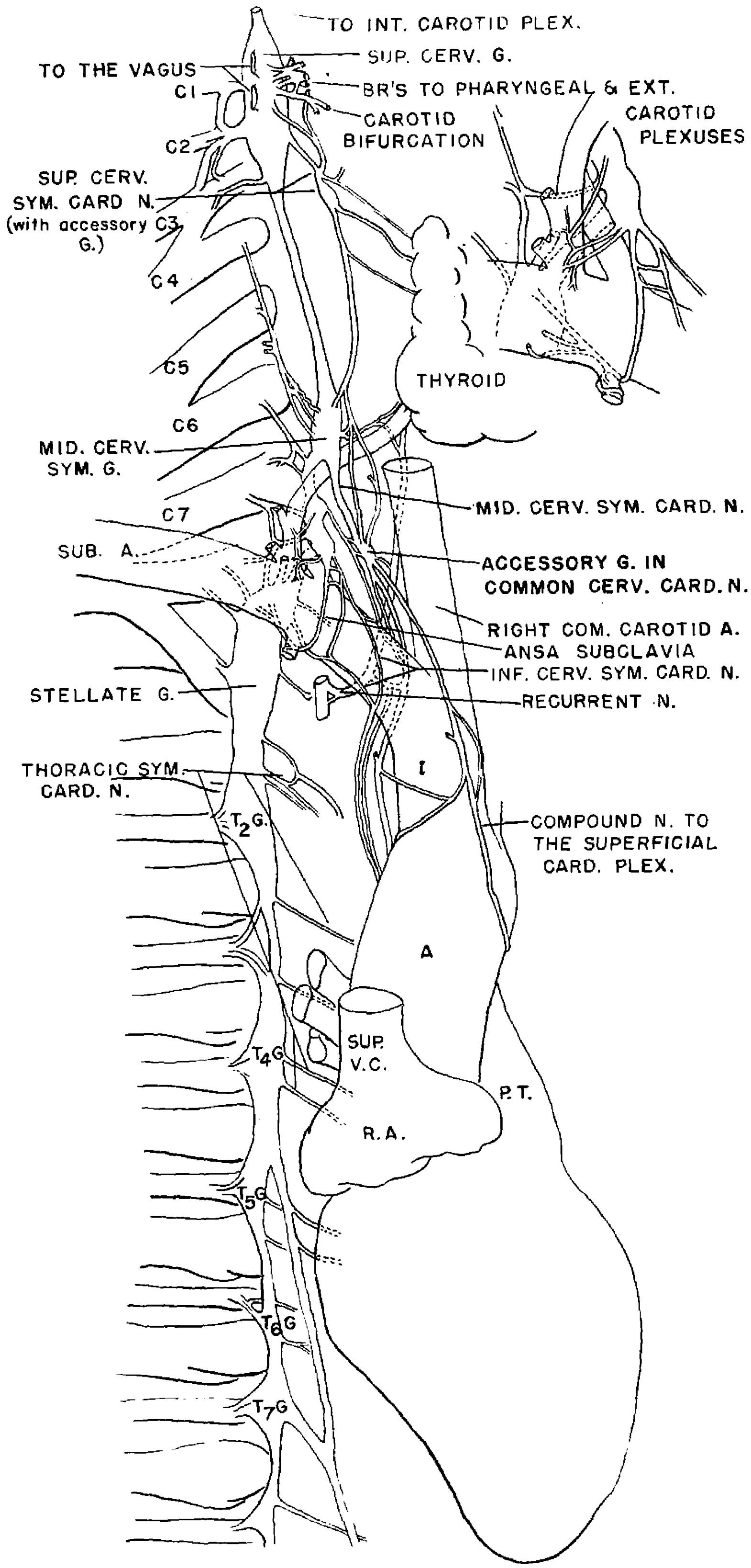
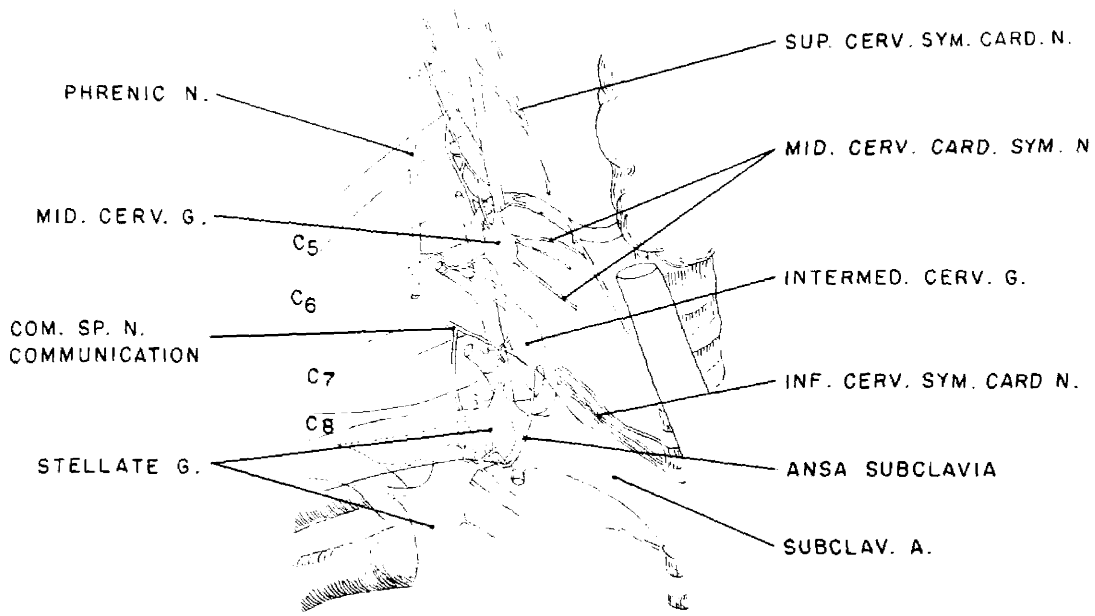

TO INT. CAROTID PLEX.
SUP. CERV. G.
TO THE VAGUS
C1
BR'S TO PHARYNGEAL & EXT.
CAROTID PLEXUSES
CAROTID BIFURCATION
C2
SUP. CERV. SYM. CARD N. (with accessory G.)
C3
C4
C5
THYROID
C6
MID. CERV. SYM. G.
MID. CERV. SYM. CARD. N.
C7
SUB. A.
ACCESSORY G. IN COMMON CERV. CARD. N.
RIGHT COM. CAROTID A.
ANSA SUBCLAVIA
INF. CERV. SYM. CARD. N.
STELLATE G.
RECURRENT N.
THORACIC SYM. CARD. N.
I
COMPOUND N. TO THE SUPERFICIAL CARD. PLEX.
T_2G.
A
SUP. V.C.
T_4G
P.T.
R.A.
T_5G
T_6G
T_7G

FIGURE 2

corresponding carotid plexuses. Other branches passed from the ganglion to the pharyngeal plexus, to the larynx, thyroid gland, and the common carotid artery. A detailed description of its cardiac branch will be given later.

The middle cervical ganglion was present in 86% of the sympathetic trunks examined, but varied considerably in size, shape, and position (Figs. 1, 2 and 3). It was often very small and frequently intimately related to the inferior thyroid artery, usually at the level of the 6th cervical vertebra. It communicated most frequently with cervical spinal nerves 4, 5 and 6, although communications with 3 and 7 were also observed. In one-third of the specimens its lower pole was joined by the ansa subclavia. The ganglion usually gave branches to the vessels in close proximity, especially the inferior thyroid artery. Its contribution to the middle cervical sympathetic cardiac nerve will be considered later.

The presence of a ganglionic enlargement of the cervical sympathetic trunk between its classically described middle and inferior ganglia was observed in 83% of the specimens (Figs. 1, 2, 3A, B, and C). It was usually located opposite the 7th cervical vertebra or slightly higher (Table 1), anterior and medial to the vertebral artery or occasionally laterally on that vessel. It was designated the intermediate cervical ganglion. In those cases in which the intermediate ganglion was not observed per se, a portion of the inferior cervical ganglion presented features which corresponded


SUP. CERV. SYM. CARD. N.
PHRENIC N.
MID. CERV. CARD. SYM. N.
MID. CERV. G.
C5
C6
INTERMED. CERV. G.
COM. SP. N.
COMMUNICATION
C7
INF. CERV. SYM. CARD N.
C8
STELLATE G.
ANSA SUBCLAVIA
SUBCLAV. A.

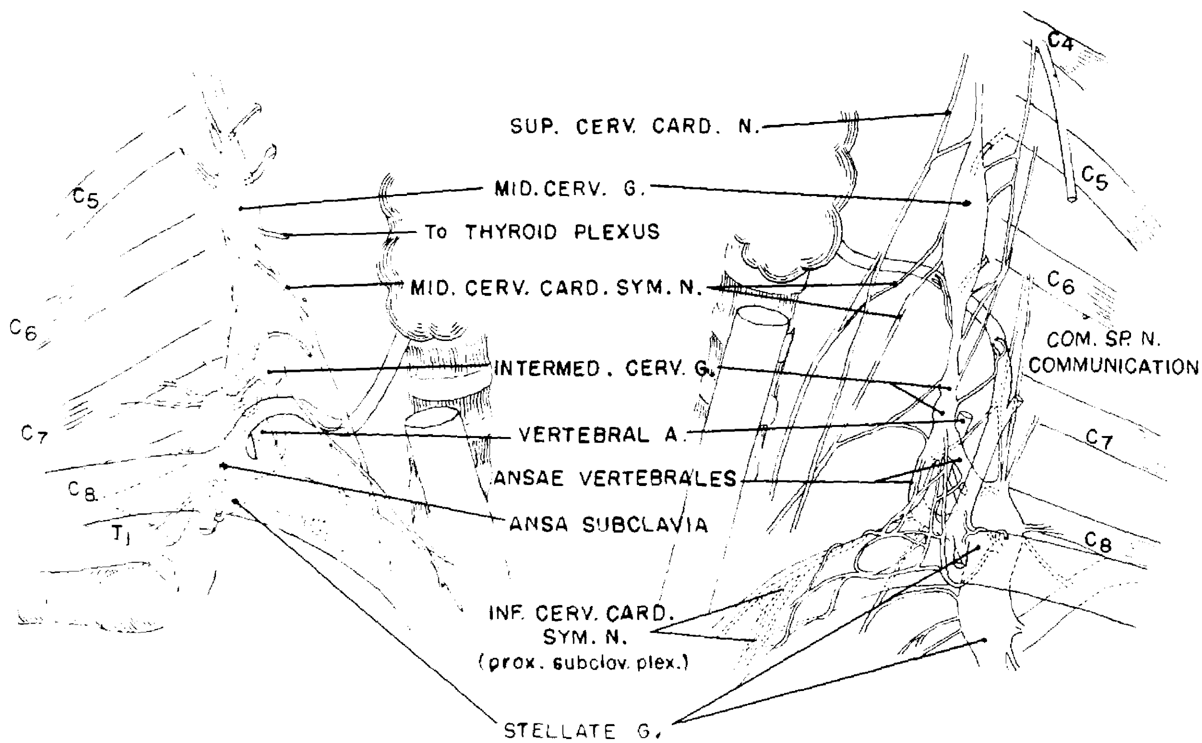

C4
SUP. CERV. CARD. N.
C5
MID. CERV. G.
C5
To THYROID PLEXUS
MID. CERV. CARD. SYM. N.
C6
C6
COM. SP. N.
COMMUNICATION
INTERMED. CERV. G.
C7
VERTEBRAL A.
C7
ANSAE VERTEBRALES
C8
ANSA SUBCLAVIA
C8
T1
INF. CERV. CARD.
SYM. N.
(prox. subclav. plex.)
STELLATE G.

FIGURE 3

to it. The trunk joining the intermediate and inferior ganglia was often (58%) very thick and usually was split by the vertebral artery into two unequal portions (Fig. 17). The ansa subclavia provided an additional link between the two ganglia in 62% of the specimens.

The trunk between the intermediate and middle cervical ganglia was not as close, however, as that of the intermediate and inferior ganglia. The intermediate ganglion was also present in the majority of the specimens which demonstrated the middle cervical ganglion, and their size, in general terms, varied reciprocally (Table 1, Fig. 3).

The 5th cervical spinal nerves communicated with the intermediate ganglion in 33%, the 6th in 58%, and the 7th in 62% of the specimens, and included branches to the 3rd, 4th, and 8th cervical spinal nerves in 1, 3, and 2 instances respectively. A trunk common to both intermediate and middle cervical ganglia united them with spinal nerves in 13% of the specimens. The inferior cervical ganglion utilized such a trunk for spinal nerve communication, in common with the intermediate, in 42%.

Branches of the intermediate cervical ganglion, which passed to vascular structures in the area, i.e., the thyrocervical trunk, the subclavian and internal mammary arteries, were present in 93% of the cases. Additional branches to the plexus of the vertebral artery were present in 22%, but were not included as vascular branches because most of the nerves comprising the proximal portion of this plexus were given off to the cervical spinal nerves within the vertebral canal. Occasional branches from the ganglion were observed passing to the esophagus and trachea, and in one instance a branch was noted which connected with the phrenic nerve.

Dissection 9R was not included in the above data, although an intermediate cervical ganglion was present with branches corresponding to those described above, because of the presence of an anomalous right subclavian artery.

No essential difference between the two sides in the various features of the intermediate ganglion was observed.

The inferior cervical ganglion was frequently distinguishable as such, but in most instances only a slight constriction separated it from the 1st thoracic (Figs. 1, 2, and 3). The large mass thus formed, the stellate ganglion, also was fused with the intermediate cervical ganglion and the 2nd thoracic ganglion in some instances (Figs. 16 and 17). This elongated ganglionic complex was located on the anterior surface of the head of the 1st rib immediately posterior to the subclavian artery. Its relatively constant spinal nerve communications were with the 7th and 8th cervical and 1st thoracic; additional communications were occasionally observed reaching as high as the 4th cervical and as low as the 3rd thoracic spinal nerves. Vascular branches passed to the plexuses about the thyrocervical trunk, internal mammary artery, and distal part of the subclavian. Through the latter plexus, a branch occasionally communicated with the phrenic nerve. An additional large branch usually accompanied the vertebral artery. The ansa subclavia, a nerve looping around the subclavian artery and coming from the middle or intermediate ganglion, joined the inferior cervical ganglion on its anterior surface near the origin of the ramus to the 1st thoracic nerve. The cardiac nerves from the inferior ganglion will be considered later.

The sympathetic trunk in the upper thoracic region consisted of a series of ganglia, located between the ribs, and the interganglionic trunks which crossed the anterior surfaces of the heads of the ribs (Figs. 1, 2, and 14). Adjacent ganglia were sometimes fused, and when such was the case, the resulting structure was found on the intervening rib. As mentioned above, the 1st and sometimes the 2nd thoracic ganglia were incorporated in the stellate ganglion. The ganglia communicated with their corresponding spinal nerves, and occasionally with those of adjacent levels. Each ganglion usually gave rise to branches which passed to the mediastinal viscera, although such branches were as often derived from the interganglionic trunks. The latter structures were sometimes doubled.

Cervical Sympathetic Cardiac Nerves

Superior Cervical Sympathetic Cardiac Nerve

The superior nerve was present in 86.3% of the specimens (Table 2). It originated by one or more roots, with an average of two, from the lower pole of the superior cervical ganglion or the sympathetic trunk immediately below (Figs. 1 and 2). A root from the trunk was present in 48%, whereas, the root from the superior ganglion was observed in all but one case. In this instance, the entire nerve arose from the trunk 0.5 cm. below the superior cervical ganglion. In 20% of the specimens there was an additional root from the external branch of the superior laryngeal nerve of the vagus.

The superior cardiac nerve descended within the carotid sheath posterior to the internal and common carotid arteries (Figs. 15, 16, and 17). It gave numerous small filaments to the arteries, which were destroyed as the dissection proceeded. The nerve was usually closely associated with the lateral aspect of the thyroid gland. In dissection 14R it passed within the connective tissue sheath of the gland. The nerve descended anterior to the inferior thyroid artery in every case except one (13L).

On the left side, all or part of the superior cardiac nerve passed anterior to the subclavian artery en route to the superficial cardiac plexus. In a single case, the nerve passed entirely to the deep cardiac plexus. On the right side the nerve descended either anterior or posterior to the bifurcation of the innominate artery and along the lateral side of that vessel. From that point it passed to the deep cardiac plexus in 92% of the instances, although a few fibers occasionally reached the superficial cardiac plexus. In dissection 9R (anomalous) the nerve passed entirely to the superficial plexus.

Filaments from the nerve were observed passing to the adventitia of the large arteries at their origins from the aortic arch and to the arch itself. A direct contribution of this nerve to the ductus arteriosus, in common with the middle cervical nerve, was observed in a single specimen (14L). Its usual termination in the superficial cardiac plexus provided an additional possible path for fibers to the ductus from this source.

Middle Cervical Sympathetic Cardiac Nerve

The middle cardiac nerve was found in all specimens examined. It arose from the middle cervical ganglion, the sympathetic trunk (proximal or distal), and occasionally from the intermediate cervical ganglion (Table 2, Figs. 1 and 2, and 3). The number of roots ranged from 1 to 6, with an average of 2.5; no appreciable difference was observed between right and left sides. The middle ganglion was the most frequent source of this nerve giving rise to at least a portion of 76% of the specimens. Of the 7 cases (24%) in which the nerve arose from other sources, 4 lacked the ganglion and the nerve took origin at the usual site of the middle cervical ganglion. In the remaining three cases, the ganglion was present but failed to supply fibers to the cardiac nerve, the entire nerve arising from the interganglionic trunk below the ganglion.

In 45% of the specimens, the middle nerve derived at least a part of its fibers from the interganglionic trunk. These roots usually originated from the trunk between the middle and intermediate ganglia. The last mentioned ganglion, or its representative in the stellate complex, gave rise to fibers which joined the middle nerve in 45% of the specimens. An apparently anomalous contribution from the 3rd cervical spinal nerve was noted in a single case.

The nerve was more often represented by several parallel strands than by a discrete trunk. In 59% of the cases it consisted of multiple strands composed of from 2 to 6 filaments in a plexiform arrangement. The nerve, or nerves, passed posterior to the common carotid artery and anterior to the inferior thyroid artery, if the origin was high or posterior to the latter if it was low. The major portion of the nerve descended behind the subclavian artery, but infrequently some fibers passed in front, and in one specimen (3R) the entire nerve was anterior (Fig. 9). The relation of the middle cervical nerve to the innominate artery on the right side was essentially the same as that for the subclavian.

The largest portion of the nerve in all specimens passed to the deep cardiac plexus, and in 35% this involved the entire nerve. Fibers to the superficial plexus were observed in 45% of the cases, although their proximal communications with other cardiac nerves interfered with their exact definition. No difference in the frequency of contribution to the superficial plexus was observed between right and left sides. Branches to the adventitia of the large arteries from the aortic arch and to the arch itself were observed in 20% of the specimens and occurred twice as frequently on the left as on the right.

Inferior Cervical Sympathetic Cardiac Nerve

This nerve was observed in all dissections but was small on the right side in 33%. It received fibers from the inferior cervical or stellate ganglion in 93%, and from the intermediate cervical ganglion, or the portion of the stellate complex which represented it in 72%, with no appreciable difference between the two sides (Table 4, Figs. 1, 2, and 3). No contribution was given by the ansa subclavia on the right; it was observed in 28% of the cases on the left. Branches of the interganglionic trunk sometimes took part in the formation of this nerve, but because these branches arose immediately adjacent to either the intermediate cervical or the stellate ganglion, they have been recorded as branches of the nearest ganglion. The number of roots forming the nerve varied from 1 to 6 and averaged 2.5 on the right and 3.2 on the left.

The parallel strands composing the inferior cardiac nerve descended into the superior mediastinum in more or less intimate association with the subclavian artery, on the left and the subclavian and innominate arteries on the right (Figs. 1, 2, and 3). A series of loops or communications between the strands of the nerve formed a plexus along the subclavian artery. The plexus occurred in 85% of the specimens on the left and in 29% on the right, and was limited, on the left, primarily to that portion of the artery between its origin and its major branches (Figs. 1, 3, 16, and 17). The plexus varied considerably in size and complexity with the greater portion of the nerves posterior to the subclavian. On the right, the branches on the anterior and superior aspect were usually regrouped at the proximal end of the subclavian and then wound around the innominate artery to gain its lateral side.

From the lower portion of the stellate ganglion a slender nerve arose, which often dissociated itself from the other strands of the inferior cervical nerve. It descended along the thoracic duct on the anterior and lateral aspect of the upper two thoracic vertebrae to the cardiac plexus (Figs. 10, 14, and 17).

The primary termination of the inferior cardiac nerve on both sides was the deep cardiac plexus, with 96.5% of the nerves contributing at least a portion of their fibers. On the left there was also a contribution to the ductus arteriosus in all cases, although in two the contribution was small. Fibers, varying in size, were given to the central portion of the superficial cardiac plexus by the left nerve in 60% of the specimens. On both sides, branches passed to the adventitia of the aortic arch and the large arteries at their origin from it. The nerve on the right may have contributed fibers to the superficial cardiac plexus in 35% of the cases by way of its communications with other cardiac nerves.

An unusual course of the nerve on the right was observed in dissection 9R, in which an anomalous right subclavian artery arose from the aorta distal to the left subclavian and passed posterior to the esophagus (Fig. 4). In this specimen, the right superior cervical sympathetic cardiac nerve ended entirely in the superficial plexus and the middle went essentially to the deep plexus, although sending a branch with the inferior cardiac nerve to form a plexus about the anomalous artery. The inferior nerve arose from the intermediate and inferior cervical ganglia, and with the branch from the middle nerve, formed a plexus which followed the anomalous vessel posterior to the esophagus to its origin from the aorta (Fig. 4). At that point, the nerves regrouped into two trunks which passed anteriorly on the medial surface of the descending aorta to the deep cardiac plexus. Vagal cardiac nerves were unaffected by this anomaly.

Cardiac Nerves of the Intermediate Ganglion

Although the cardiac branches of the intermediate cervical ganglion formed, in part, the middle or inferior cardiac nerves, as has been described above, it should be noted that 22% of them passed directly to either the deep or superficial cardiac plexuses unassociated with any other cardiac nerves.

Thoracic Sympathetic Cardiac Nerves

A series of visceral branches from the upper portion of the

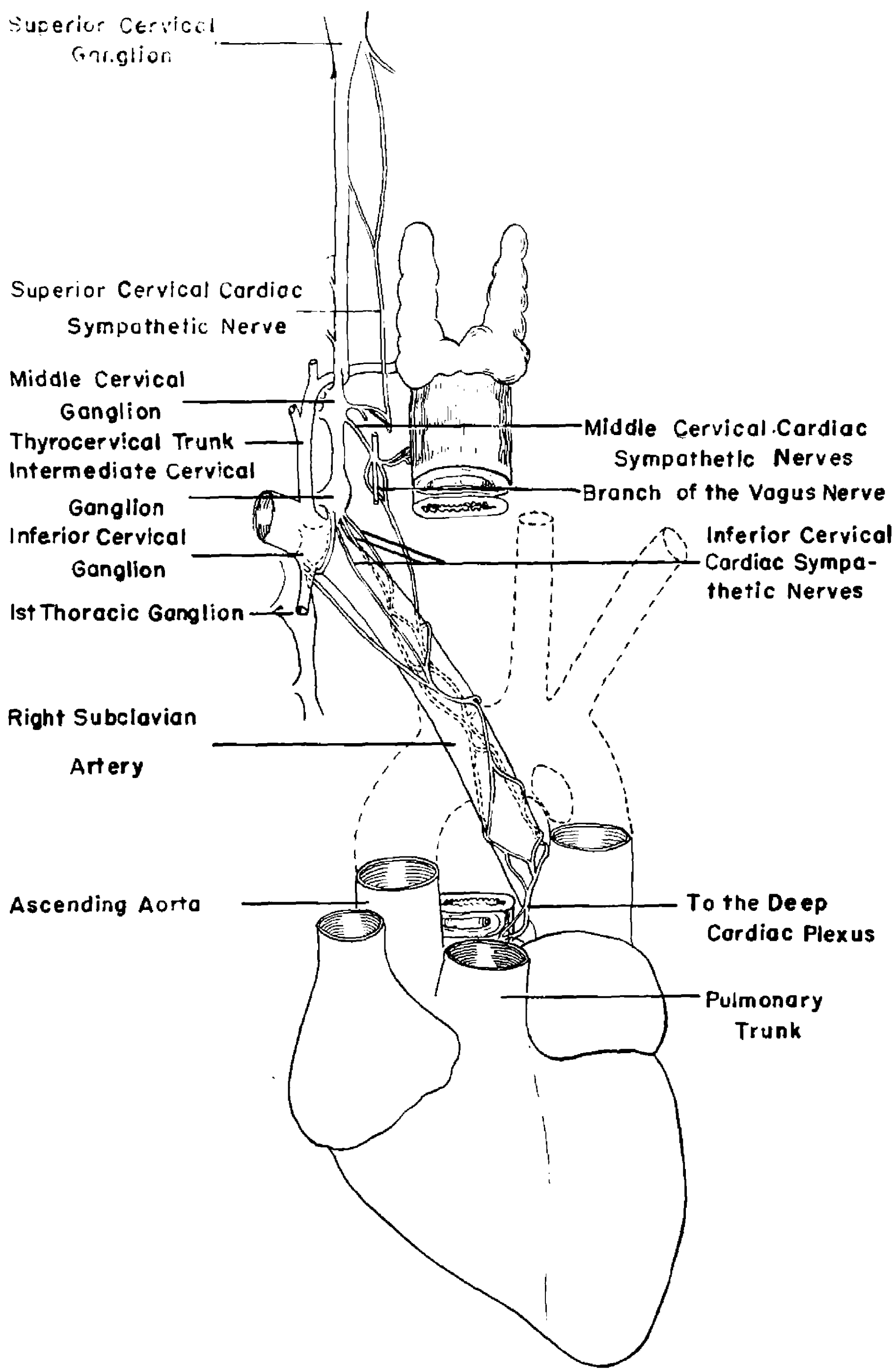

Superior Cervical Ganglion
Superior Cervical Cardiac Sympathetic Nerve
Middle Cervical Ganglion
Thyrocervical Trunk
Intermediate Cervical Ganglion
Inferior Cervical Ganglion
1st Thoracic Ganglion
Right Subclavian Artery
Ascending Aorta
Middle Cervical Cardiac Sympathetic Nerves
Branch of the Vagus Nerve
Inferior Cervical Cardiac Sympathetic Nerves
To the Deep Cardiac Plexus
Pulmonary Trunk

Figure 4

thoracic sympathetic trunk, from either its ganglia or the interganglionic segments passed medially into the mediastinum. The larger proportion of these nerves were destined for the heart or the aorta and were designated thoracic sympathetic cardiac nerves (Table 5, Figs. 1, 2, 10, and 14). Only those nerves arising from the upper 6 thoracic ganglia have been included in this analysis, although occasionally filaments from lower levels reached the aortic plexus. Although the first thoracic ganglion, as part of the stellate, was considered a source of the inferior cervical cardiac nerve, its inclusion here is based on the presence of a nerve from it more typical of the thoracic cardiac nerves.

The thoracic cardiac nerves on each side numbered about 10 when all branches, regardless of size, were counted (10.3 on the right and 9.4 on the left). Variation in the number of these nerves in each specimen was considerable and ranged from 6 to 13 on the right and 6 to 17 on the left.

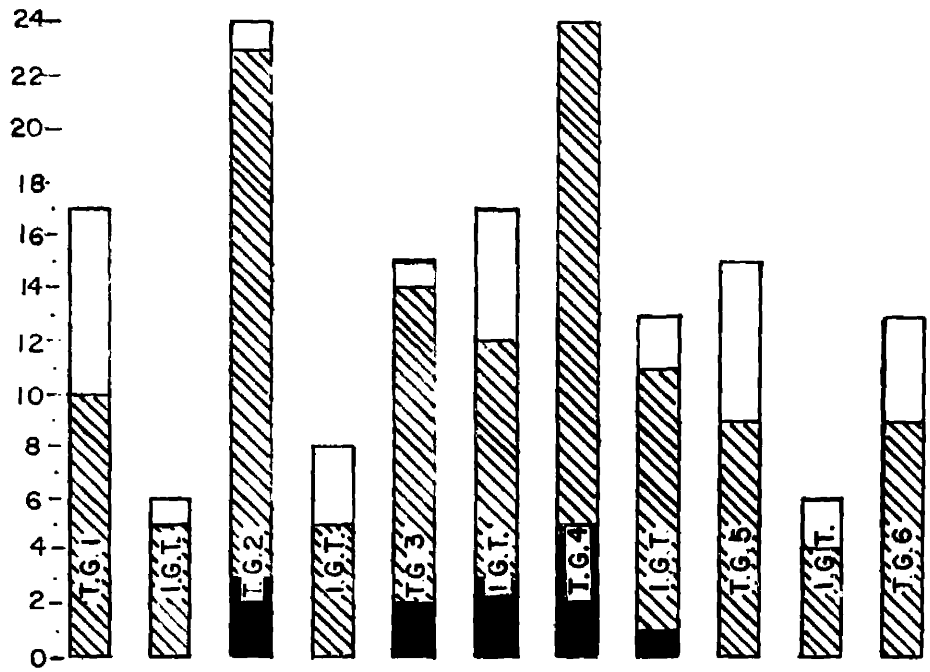
The second thoracic ganglion gave rise to the cardiac nerves on each side in 93% of the specimens. The 4th ganglion gave rise to cardiac branches in 93% on the right and 80% on the left; branches arose from the third ganglion on the right in 79%, and on the left in 80% of the specimens. The 1st, 5th and 6th ganglia contributed to the cardiac or aortic plexuses in 93%, 66%, and 53% respectively on the right, and on the left the contribution was the same (60%) from all three ganglia.

Of the interganglionic segments, the one between thoracic ganglia 3 and 4 gave rise to cardiac nerves most frequently, 71% on the right, 67% on the left; that between ganglia 4 and 5, 66% on the right, 53% on the left; 2 and 3, 53% on the right, 47% on the left; 1 and 2, 29% on the right, 47% on the left; 5 and 6, 33% on the right, and 33% on the left.

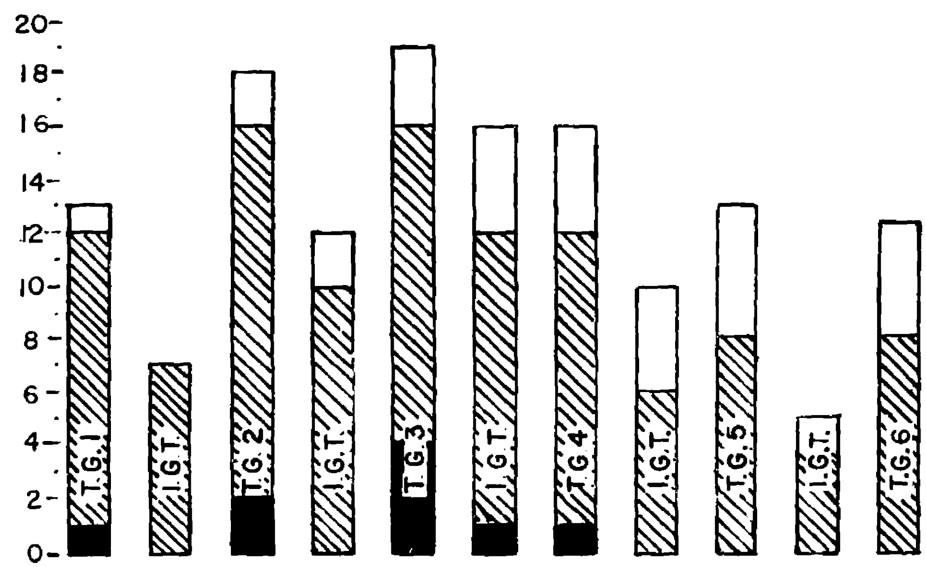
The number of nerves from each ganglion or interganglionic segment are shown in Figure 5, in which the total number of nerves from each source in all specimens is recorded.

The uppermost roots of the greater splanchnic nerve sometimes interfered with the study of the lower thoracic cardiac nerves, but in all instances the nerves were dissected as far as possible, to their probable source.

The thoracic cardiac nerves extended into the deep cardiac or the aortic plexus, depending upon the level at which they arose, i.e., those from the upper three thoracic ganglia passed to the deep cardiac plexus, with the exception of the branches to the ductus arteriosus; those from lower ganglia passed to the aortic plexus. They usually accompanied the aortic intercostal vessels, especially the artery, but some of them passed directly. On the right side, filaments from the lower ganglia followed the azygous vein to the posterior surface of the superior vena cava and, thence, to the deep cardiac plexus. Additional branches on the same side passed posterior to the azygous vein to reach the aortic plexus directly.



RIGHT SIDE



LEFT SIDE

Figure 5

The majority of thoracic cardiac nerves on the right side passed to the deep cardiac plexus, while those on the left passed to the deep and the aortic plexuses in approximately equal numbers. Some of the fibers on the left descended anterior to the aorta and reached the superficial cardiac plexus. The aortic and deep cardiac plexuses communicated on the medial side of the aorta just below the arch.

Intercommunications of the Sympathetic Cardiac Nerves

Communications between the various sympathetic cardiac nerves were frequently observed. These were divided into three main groups: intercervical, cervicothoracic, and interthoracic.

Communications involving at least two of the cervical cardiac nerves were present in 93% of the specimens and most frequently involved the superior and middle nerves. These nerves communicated in 88% of the specimens in which both were present. Communications between the middle and inferior cardiac nerves were observed in 66% of the specimens, and although no appreciable difference in frequency of communication on right and left sides was noted, the size of the communication was appreciably smaller on the left. The superior and inferior nerves communicated (in part) in 16% by a branch of the former nerve to the proximal subclavian plexus, and in still other instances by a common cervical cardiac nerve.

The occurrence of a common trunk formed by the fusion of several or all of the cervical candiac nerves was observed in 35% of the specimens and always included the middle nerve. The trunk was present on both sides with equal frequency, but the complex of nerves usually appeared more compact on the right side. The common trunk, instead of continuing to the cardiac plexus per se, usually separated into 2 to 4 terminal branches. The termination of these branches varied according to the nerves which were incorporated in the trunk, but most of them ended in the deep cardiac plexus.

The cervicothoracic communications involved portions of the inferior cervical cardiac nerves, often through branches of the proximal subclavian plexus, and the uppermost thoracic cardiac nerves. It was usually observed, however, that the portion of the inferior nerve, if it can be so called, most frequently involved was derived from the inferior portion of the stellate ganglion corresponding to the first thoracic ganglion. In 47% of the specimens on the left, and in 21% on the right, the contribution from the inferior cervical nerve took part in the formation of a well defined collateral chain or trunk (Fig. 10). In the other cases a simple union of a branch of the stellate ganglion with a branch of the second thoracic ganglion occurred.

Interthoracic nerve communications were a relatively constant feature. The degree of complexity varied considerably, being more marked among the upper thoracic cardiac nerves. There were examples of a simple exchange of fibers between adjacent nerves, arch formation by complete fusion of a series of adjacent nerves, formation of a collateral trunk roughly paralleling the descending aorta, and formation of a complex network of nerves along the lateral sides of the vertebral bodies (Figs. 1, 2, 9, 10, 14, and 17). The nerves from the 4th thoracic and lower ganglia usually passed directly to the aortic plexus.

On the right side, the nerves passed directly to the cardiac or aortic plexuses in 53% of the bodies examined. In 20% of the remaining specimens, a collateral trunk was observed. A plexiform arrangement of the nerves was found in an additonal 20%, and a single example of arch formation occurred. On the left side a collateral trunk was found in 47%, arch formation in 20%, direct branches in 20%, and plexiform networks in 13%.

Accessory Ganglia associated with Sympathetic Cardiac Nerves

Small ganglionic enlargements of the cardiac nerves were variable in their frequency of occurrence, position, and size (Figs. 1, 2, 9, 10, and 13). Occasionally the enlargement was found in the course of a nerve unassociated with other nerves in the vicinity but, more frequently, the ganglia were found at the union of several cardiac nerves or their branches. Such ganglia were sometimes noted at the terminations of large nerves which divided into numerous smaller branches. Only those ganglia which were completely separated from the sympathetic trunk are considered here, although the enlargement of a nerve at its origin, as if a small ganglion were present, was often observed.

Accessory ganglia, which appeared to be confined to the superior cardiac nerve were observed in 36% of the specimens. By union with the middle cardiac nerve the superior was associated with an additional 5 ganglia on the left. Occasionally two ganglia were observed in the course of a single nerve. The point in the superior nerve at which these ganglia appeared was either near its origin or at the entrance of the nerve into the thorax, with the majority in the latter position.

Accessory ganglia of the middle cardiac nerve alone were found in 20% of the specimens on the left and 13% on the right. In other specimens, 33% on the left and 20% on the right, there were ganglia common to both superior and middle nerves. A ganglion was found, therefore, in the latter nerve on the left in 57% of the specimens examined and on the right in 37%. In this nerve, the ganglion usually lay opposite the 7th cervical vertebra.

The accessory ganglia associated with the inferior cardiac nerve comprised those which were found in the nerves of the subclavian plexus (41% of the specimens on the left, none on the right) and those associated with the thoracic cardiac nerves (20% on the left and 13% on the right). The ganglia associated with the nerves of the subclavian plexus are characteristically small but well defined (Figs. 9 and 13).

Including the ganglia with both inferior cervical and thoracic nerve contributions, accessory ganglia of the thoracic cardiac nerves were found in 53% of the specimens on the left and 40% on the right. These ganglia were observed most frequently in association with the nerves, from the 1st, 2nd, and 3rd thoracic ganglia. Those specimens which had a collateral chain or trunk usually had two or three ganglia within the chain.

Cardiac Nerves of the Vagus

The cardiac branches arising from the vagus above the 6th cervical spinal nerve were considered part of the superior cervical cardiac nerves, whereas, those arising below this point, but above the lower border of the subclavian artery are included in the inferior nerves (Table 6, Figs. 6 and 7).

Superior Cervical Cardiac Nerves

Although small upper cervical branches of the vagus, of probable cardiac distribution, were found in 75% of the specimens examined, only 14% formed a relatively independent branch. In all other cases the vagal representative joined the superior sympathetic cardiac nerve. It varied in frequency and size on the two sides, being present in 71% on the left and 79% on the right, half the nerves on both sides being very small.

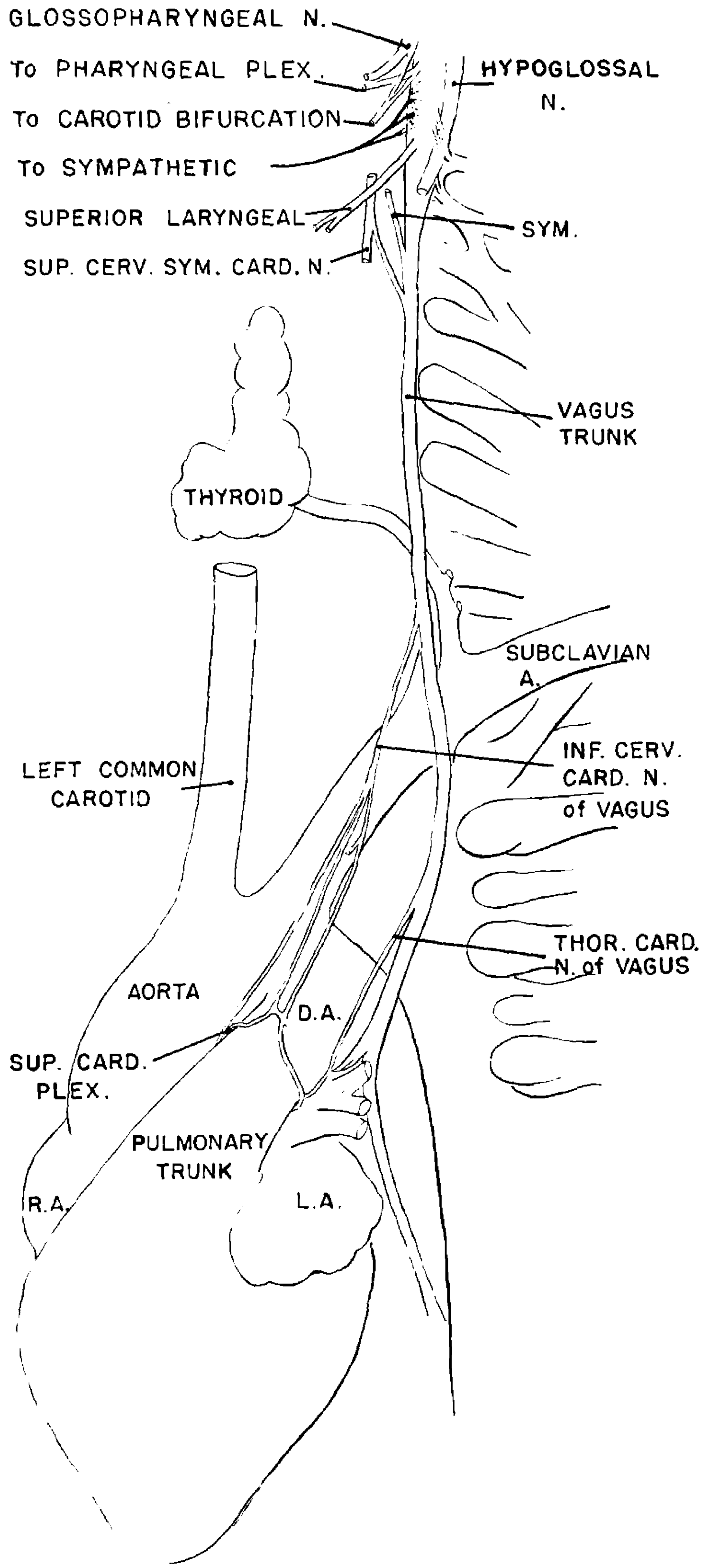

GLOSSOPHARYNGEAL N.
To PHARYNGEAL PLEX.
To CAROTID BIFURCATION
To SYMPATHETIC
SUPERIOR LARYNGEAL
SUP. CERV. SYM. CARD. N.
HYPOGLOSSAL N.
SYM.
VAGUS TRUNK
THYROID
SUBCLAVIAN A.
INF. CERV. CARD. N. of VAGUS
LEFT COMMON CAROTID
THOR. CARD. N. of VAGUS
AORTA
D.A.
SUP. CARD. PLEX.
PULMONARY TRUNK
R.A.
L.A.

FIGURE 6

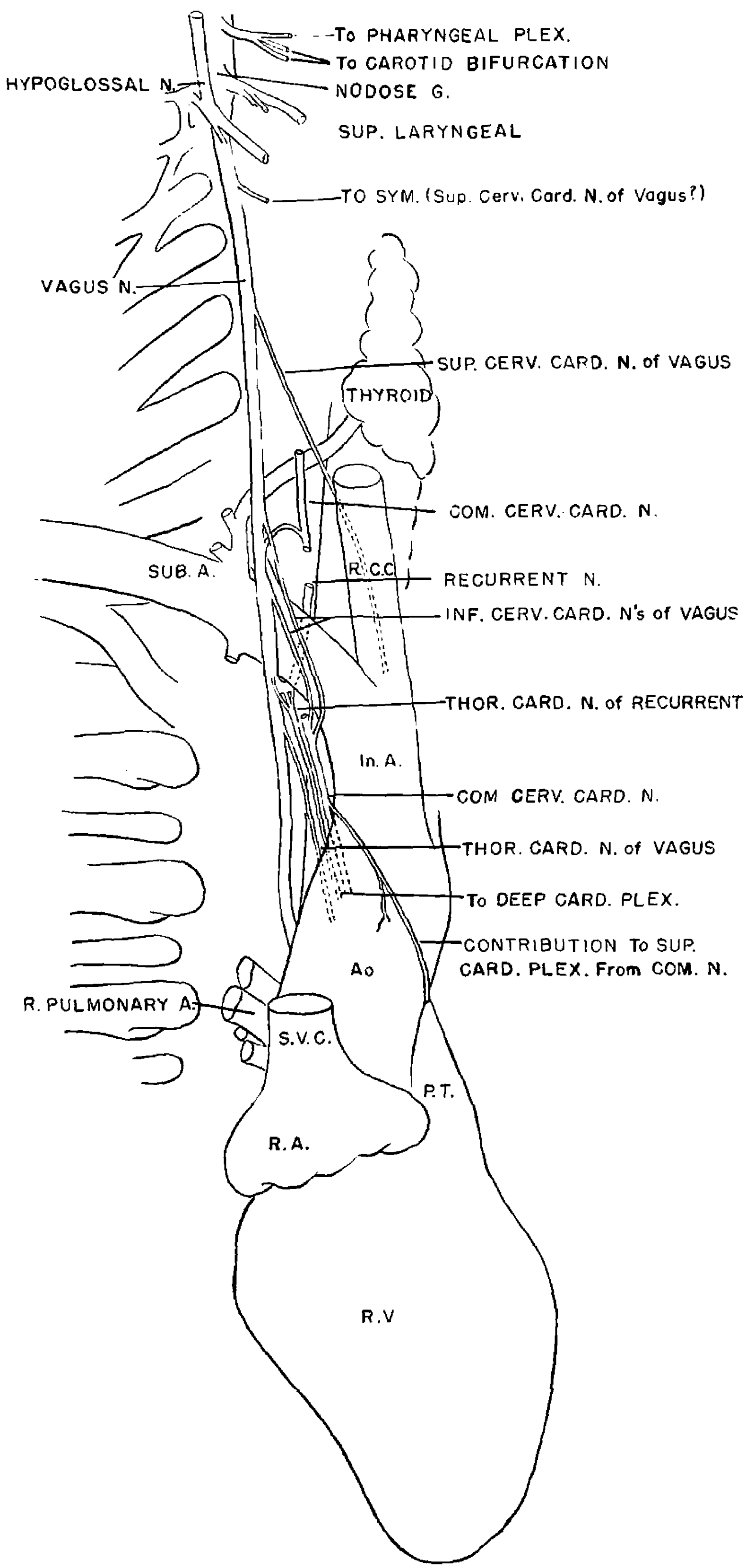

To PHARYNGEAL PLEX.
To CAROTID BIFURCATION
HYPOGLOSSAL N.
NODOSE G.
SUP. LARYNGEAL
TO SYM. (Sup. Cerv. Card. N. of Vagus?)
VAGUS N.
SUP. CERV. CARD. N. of VAGUS
THYROID
COM. CERV. CARD. N.
SUB. A.
R.C.C
RECURRENT N.
INF. CERV. CARD. N's of VAGUS
THOR. CARD. N. of RECURRENT
In. A.
COM CERV. CARD. N.
THOR. CARD. N. of VAGUS
To DEEP CARD. PLEX.
CONTRIBUTION To SUP. CARD. PLEX. From COM. N.
Ao
R. PULMONARY A.
S.V.C.
P.T.
R.A.
R.V

Figure 7

The termination of the fibers belonging to the superior nerve was difficult to determine because of communications with other nerves. Branches were traced to the aortic arch, the subclavian and common carotid arteries at their origins, and the cardiac plexuses, especially the deep.

Inferior Cervical Cardiac Nerve

An inferior cardiac nerve was observed in 96% of the specimens examined. It usually represented the major contribution of the vagus to the heart and often arose by several roots. The most frequent site of origin, on both sides, was opposite the upper border of the subclavian artery, although other branches arose from the vagus near the upper and lower limits set for its origin. In two specimens (7%), in which it arose from the vagus at the upper limit, i.e., opposite the 6th cervical spinal nerve, no superior cardiac nerve was found.

The major portion of the inferior cardiac nerve passed anterior to the subclavian artery on both sides. On the left, it terminated in the superficial cardiac plexus in all but one instance, in which it was small and joined the proximal subclavian plexus, leaving the superior nerve to contribute to the superficial plexus. In 43% on the left side, some of its branches terminated in the adventitia of the aorta at the origin of the common carotid artery, and in 55% in the plexus upon the ductus arteriosus.

On the right, the nerve passed around the lower border of the subclavian artery at its origin and continued along the posterior and lateral surface of the innominate artery to the deep cardiac plexus. In 57% of the specimens some, and in one instance all of the branches of the nerve terminated in the adventitia of the innominate artery at its bifurcation. A possible contribution to the superficial cardiac plexus was present in 57% of the specimens.

Thoracic Cardiac Nerves

Thoracic cardiac nerves arose from either the vagus nerve proper or from its recurrent branch. The superior limit for the origin of the thoracic vagal branches, as already mentioned, is the lower border of the subclavian artery.

On the left side, thoracic nerves were noted in 79% of the specimens and through duplication averaged 1.7 in each of these. They were divisible by origin into three types; high, between the lower border of the subclavian artery and a point 1.5 cm. into the thorax (36%); low, near the point at which the vagus crossed the aortic arch (36%); and from the recurrent nerve as it looped beneath the ductus arteriosus (21%).

On the right, these nerves were present in all specimens examined with an average of 2.6 nerves in each. In 57% of the specimens, cardiac branches were observed passing from both the recurrent nerve and the vagus trunk. In 21%, one or more nerves arose from the recurrent nerve only and in another 21%

nerves were noted arising from the vagus only.

The terminations of the nerves differed on each side of the body. On the left side, the nerves which arose high in the thorax passed solely to the superficial cardiac plexus. Those which arose from the vagus as it approached the aorta and those from the recurrent nerve passed to the deep cardiac plexus by looping beneath the ductus arteriosus, giving fine branches to its inferior surface. One nerve, arising from the vagus midway between the high and low types of origin, passed to the ductus arteriosus where it separated into two branches, one passing directly to the superficial cardiac plexus, and the other looping around the ductus to reach the deep plexus.

On the right side the deep cardiac plexus received all of the cardiac nerves in 43% of the specimens and the major portion of the nerves in 57%. A relatively small number of the nerves last mentioned passed to the complex which contributed nerves to both plexuses.

Communications between Sympathetic and Vagal Cardiac Nerves

Numerous communications between sympathetic and vagal cardiac nerves were observed in most specimens; they varied from complete fusion to simple exchange of small branches. The communications comprised those between the vagus, its branches and the sympathetics, and those between the sympathetic and vagal branches.

Vago- Sympathetic Communications

The superior cervical cardiac nerve of the vagus was most frequently (86%) incorporated into the superior sympathetic nerve, and the remaining nerves (14%) also communicated in part. There was no appreciable difference between the two sides. This communication with the superior sympathetic nerve allowed the corresponding branch of the vagus to communicate with the middle sympathetic nerve also. In addition to these, branches to the middle sympathetic nerve were observed in 45% of the specimens in which this nerve was present. The inferior vagal nerve communicated with the sympathetic less frequently and less completely. On the left side, it was connected with the superior sympathetic nerve in 54% and, in these cases, additional communications were noted with the inferior sympathetic nerve in 38% by way of connections with the proximal subclavian plexus. On the right, communications with the sympathetic occurred in 79%, by way of union with the common trunk (essentially the middle sympathetic nerve) formed in the cervical region. However, in one instance, the communication was with the superior sympathetic nerve alone, and in another specimen there was a small branch to the inferior sympathetic nerve.

Communications between the thoracic cardiac nerves of the vagus and the cervical sympathetics varied on the two sides. On the left they occurred infrequently as small branches to the proximal subclavian plexus or with branches in or approaching the superficial cardiac plexus. On the right, the communications were found in 57% of the cases; they consisted of branches to a nerve complex on the posterior and lateral aspect of the innominate artery. This complex was derived from the common cervical cardiac trunk.

Sympathetico-Vagal Communications

The superior sympathetic nerve, when present, demonstrated two types of communication with the vagal cardiac nerves: 1) a communication high in the neck including all or part of the superior cervical nerve of the vagus in 84%; and 2) a communication lower in the neck, opposite the point of crossing of the subclavian artery, with the inferior vagal nerve in 50% on the left and 17% on the right.

The middle cervical sympathetic cardiac nerve had communications with the vagus in 90% of the specimens. It gave fibers to the vagal cardiac branches in 28%, to the left recurrent in 60%, and to the right recurrent in 36%.

The inferior sympathetic nerve communicated with the cervical cardiac branches of the vagus on the left in 33%, and with the recurrent nerve in 13%. On the right, the most frequent types of communication were with the recurrent nerve in 43%, and with the inferior cardiac nerve of the vagus in 29%.

Superficial Cardiac Plexus

The superficial cardiac plexus was formed by groups of nerves whose center was found in the concavity of the aortic arch and whose component fibers spread over the superficial surface of the aorta, pulmonary trunk, and ductus arteriosus. It was divisible into 1) a preaortic portion anterior to the ascending aorta and the arch, 2) a preductal portion laterally (anterior to the ductus arteriosus and the pulmonary trunk), and 3) a central portion between the aorta and the ductus (Figs. 1, 10, 15, 16, 17).

The nerves to the superficial plexus communicated with each other as they crossed the anterior surface of the aortic arch, and in the concavity of the arch formed a network which either dipped into the cleft between the arch and the ductus arteriosus or, continued upon the anterior surface of the ductus more laterally.

On the left side, in 85% of the dissections in which the superior sympathetic cardiac nerve was present, all or a portion of the nerve reached the superficial plexus, especially the preaortic and central portions. On the same side, the middle sympathetic nerve contributed fibers to the plexus in 29%, with possible contributions occurring in an additional 43%. The inferior sympathetic nerve contributed a portion of its fibers to the superficial plexus, especially to the lateral or preductal portion, in all specimens, although the contribution was small in two of them. The left thoracic sympathetic nerves contributed fibers to the lateral portion of the superficial plexus in 47%.

The left inferior cardiac branches of the vagus gave fibers to the superficial plexus in all cases. In one specimen, however, this contribution was small and doubtful. A contribution of fibers from the left superior vagal nerve to the superficial plexus was made possible by the communication with the superior sympathetic nerve in 71%, but actual contribution of this nerve was certain in only a single case. Branches of the left vagus arising within the thorax reached the plexus in 40% of the specimens in which cardiac branches from this portion of the vagus existed. The recurrent nerve on this side gave no branches to the superficial plexus, and its branches to the ductus were limited to the inferior and deep parts of that vessel.

A nerve, which was occasionally doubled, crossed the aortic arch obliquely from the right side of the innominate artery near its origin and entered the central portion of the superficial cardiac plexus (Figs. 1, 2, 9, 10, 12, 13, 18). This nerve was observed in 86% of the specimens and was usually composed of fibers from several sources, both sympathetic and vagal. It was derived from a complex of nerves located on the posterior and lateral side of the innominate artery, and was usually a continuation of the common cervical cardiac trunk described above. Fibers of the right superior sympathetic nerve, when it existed, were probable components of this nerve in 46%, and certain components in 15%. Of the latter, in one specimen (9R) the entire superior sympathetic nerve passed to the superficial cardiac plexus by this route. The nerve contained definite fibers of the middle cervical sympathetic in 21% of the specimens, with possible contributions in 43%. A single specimen was found with an obvious contribution from the inferior sympathetic nerve, and possible contributions from this source were seen in 50%. The inferior cervical cardiac nerves of the vagus gave fibers to this nerve in 21%, with possible contributions in 43%. The other branches of the vagus on the right supplied no definite contribution, although the possibility existed in 23%.

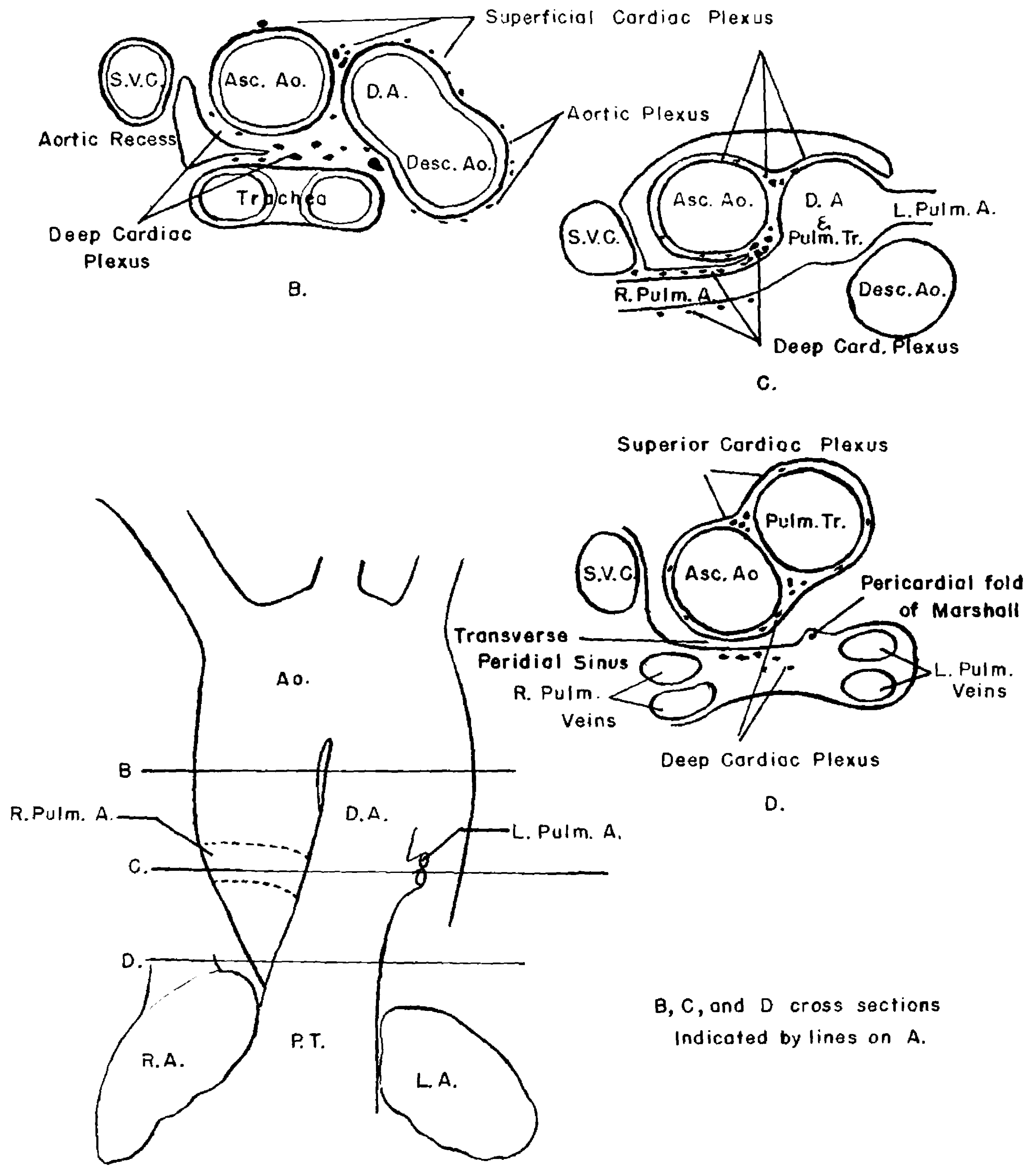
Within the superficial plexus, the contribution from the right side remained somewhat separate from the other components of the plexus, passed inferiorly, forming a delicate network anterior to the ascending aorta, and crossed again to the right of that vessel.

Most frequently, the nerves of the lateral portion of the superficial plexus which did not terminate in the adventitia of the ductus or pulmonary trunk formed a well defined nerve, which descended along those vessels and passed through the deep cardiac plexus to end in the left coronary plexus (Figs. 10 and 13). Fibers of the superficial plexus located on the medial surface of the ductus and the pulmonary trunk usually joined those fibers from the central portion passing to the right coronary plexus. Most of the nerves derived from the central portion of the plexus also continued toward the heart between the ascending aorta and the pulmonary trunk to reach the right coronary plexus. A loop between the right and left coronary plexuses was often observed passing across the pulmonary trunk at its origin from the conus arteriosus (Figs. 16 and 17).

Deep Cardiac Plexus

The deep cardiac plexus was small and circumscribed; most of it was situated along the upper border of the right pulmonary artery (Table 8, Fig. 8). Plexus formation was not evident until the nerves approached the superior border of the vessel. The center of the plexus was on the superior border of the right pulmonary artery anterior to the origin of the left bronchus. At this point the plexus was also posterior to the junction of the ascending aorta and the arch. The nerves entering into the plexus descended anterior to the trachea as parallel strands with relatively few intercommunications below the cervical region. The peripheral limits of the plexus were difficult to determine because the union and intercommunication of contributory nerves did not occur at a given point.

The greater part of the deep cardiac plexus was located posterior to the transverse pericardial sinus and its upward continuation, the aortic recess (Fig. 8). This applied particularly to the nerves on the right. The left extremity of the plexus was in contact with the posterior surfaces of the aorta, ductus arteriosus, and pulmonary trunk. The nerves in the latter situation were primarily from the left side, although a contribution from the right, often large, constantly reached this area. Frequently, a relatively small nerve, or group of nerves, reached the posterior surface of the aorta above the pericardial reflection at the upper extent of the aortic recess and


Superficial Cardiac Plexus
S.V.C.
Asc. Ao.
D.A.
Aortic Plexus
Aortic Recess
Desc. Ao.
Trachea
Deep Cardiac Plexus
B.
Asc. Ao.
D. A & Pulm. Tr.
L. Pulm. A.
S.V.C.
Desc. Ao.
R. Pulm. A.
Deep Card. Plexus
C.
Superior Cardiac Plexus
Pulm. Tr.
S.V.C.
Asc. Ao
Pericardial fold of Marshall
Transverse Peridial Sinus
L. Pulm. Veins
R. Pulm. Veins
Deep Cardiac Plexus
D.
Ao.
B
R. Pulm. A.
D.A.
L. Pulm. A.
C.
D.
P.T.
R.A.
L.A.
B, C, and D cross sections Indicated by lines on A.

A.

Figure 8

continued down along the vessel anterior to the aortic recess and, lower down, the transverse pericardial sinus.

The middle and inferior cervical, and the thoracic sympathetic nerves on both sides contributed the major portion of their fibers to the deep plexus.

When present, the superior cervical sympathetic nerve on the left side sent all of its fibers to the deep plexus in 8% and most of its fibers in 39% of the specimens. It contributed no fibers to the deep plexus in the remaining 54%. On the same side, it was noted that of 11 cases in which superior cardiac nerve of the vagus or communications representing it were found, 64% contributed a sizeable portion of their fibers to the deep plexus. On the left, 31% of the inferior cervical nerves of the vagus gave a few branches to this plexus. On the other hand, all of the cardiac branches of the recurrent nerve or the left vagus trunk in the thorax passed to the deep plexus except that those arising high in the thorax, i.e., near the upper thoracic aperture, always passed to the superficial cardiac plexus.

On the right side the superior cervical sympathetic cardiac nerve when present, sent the greater part of its fibers to the deep plexus in 83%, whereas, the corresponding nerve of the vagus sent fibers in 73% of the specimens. All other vagal cardiac nerves on the right side contributed the major, often entire, portion of their fibers to the deep cardiac plexus.

The nerves into the right extremity of the plexus, usually isolated low cervical or thoracic cardiac branches of the right vagus, passed posterior to the aortic recess and the transverse sinus, divided, and continued either anterior or posterior to the right pulmonary artery. Those which passed anterior deviated slightly to the right and reached the base of the superior vena cava and the right atrium. The nerves which passed posterior to the right pulmonary artery, still including only those nerves in the right half of the plexus, extended inferiorly to the reflection of pericardium between the transverse and oblique sinuses. Through this septum, actually the venous mesocardium, the nerves passed to the posterior surfaces of the atria between the openings of the pulmonary veins.

Nerves from the left half of the deep plexus extended to the heart anterior and posterior to the right pulmonary artery. Those anterior to the vessel followed the posterior surface of the aorta to its base, where they entered into the left coronary plexus. Of those which passed posterior to the right pulmonary artery, some went through the venous mesocardium to the atria as described above, whereas others continued along the posterior surface of the artery and the pulmonary trunk. Within the pericardial cuff enclosing the latter vessel and the aorta, the nerves reached the heart where they entered into the coronary plexuses, especially the left.

In the description of the superficial cardiac plexus, mention was made of a nerve on the inferior or lateral border of the ductus arteriosus and pulmonary trunk which passed to the left coronary plexus (Figs. 10 and 13). However, at the upper reflection of the pericardium of the transverse sinus on the left, a portion of the nerve passed posterior to the sinus, forming a slight ridge on its wall, and penetrated the venous mesocardium to reach the posterior surface of the left atrium.

Communications between the superficial and deep cardiac plexuses, although variable, were observed at three points: 1) on the right side of the aorta, 2) between the ascending aorta, its arch and the ductus arteriosus or the pulmonary trunk, and 3) on the inferior or lateral surface of the ductus arteriosus.

Nerve Supply of the Ductus Arteriosus

The ductus arteriosus received its sympathetic nerve supply from cardiac nerves of the lower cervical and upper thoracic trunk (Table 9, Figs. 9, 10, 11, 12, 13, 14, 15). Cervical branches of the left vagus to the superficial cardiac plexus were associated with, and supplied fibers to the superior and medial surfaces of the ductus, whereas, thoracic cardiac nerves of the vagus passed to the inferior and deep portions of the structure.

The most frequent and only constant source of nerves to the ductus was the inferior cervical sympathetic cardiac nerve (Fig. 11). In two specimens the nerves from this source were exceedingly fine. In one of the specimens, dissection 4, the majority of the sympathetic

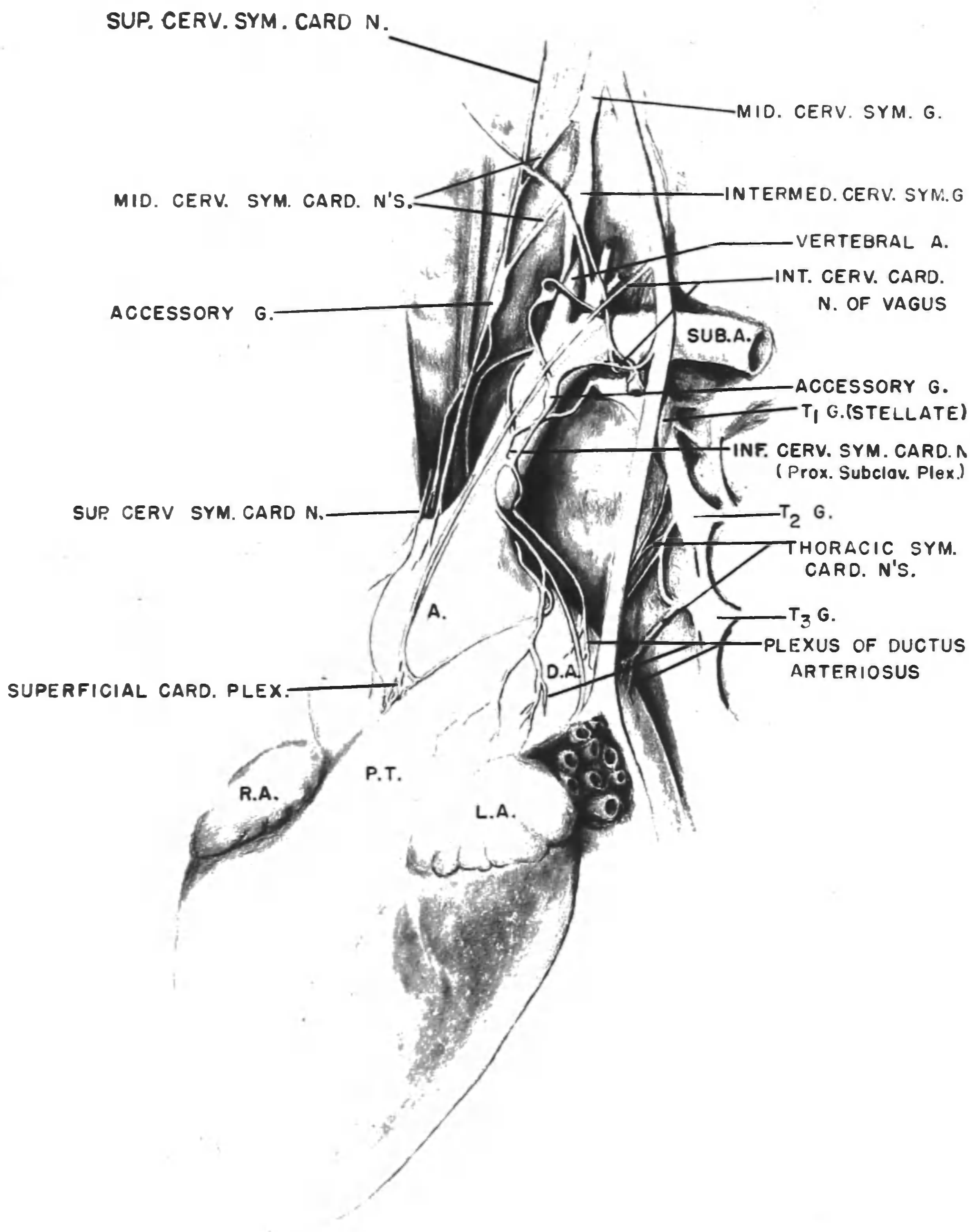

SUP. CERV. SYM. CARD N.
MID. CERV. SYM. G.
MID. CERV. SYM. CARD. N'S.
INTERMED. CERV. SYM. G
VERTEBRAL A.
INT. CERV. CARD. N. OF VAGUS
ACCESSORY G.
SUB.A.
ACCESSORY G.
T_1 G.(STELLATE)
INF. CERV. SYM. CARD. N
(Prox. Subclav. Plex.)
SUP. CERV SYM. CARD N.
T_2 G.
THORACIC SYM. CARD. N'S.
A.
T_3 G.
PLEXUS OF DUCTUS ARTERIOSUS
D.A.
SUPERFICIAL CARD. PLEX.
P.T.
R.A.
L.A.

FIGURE 9

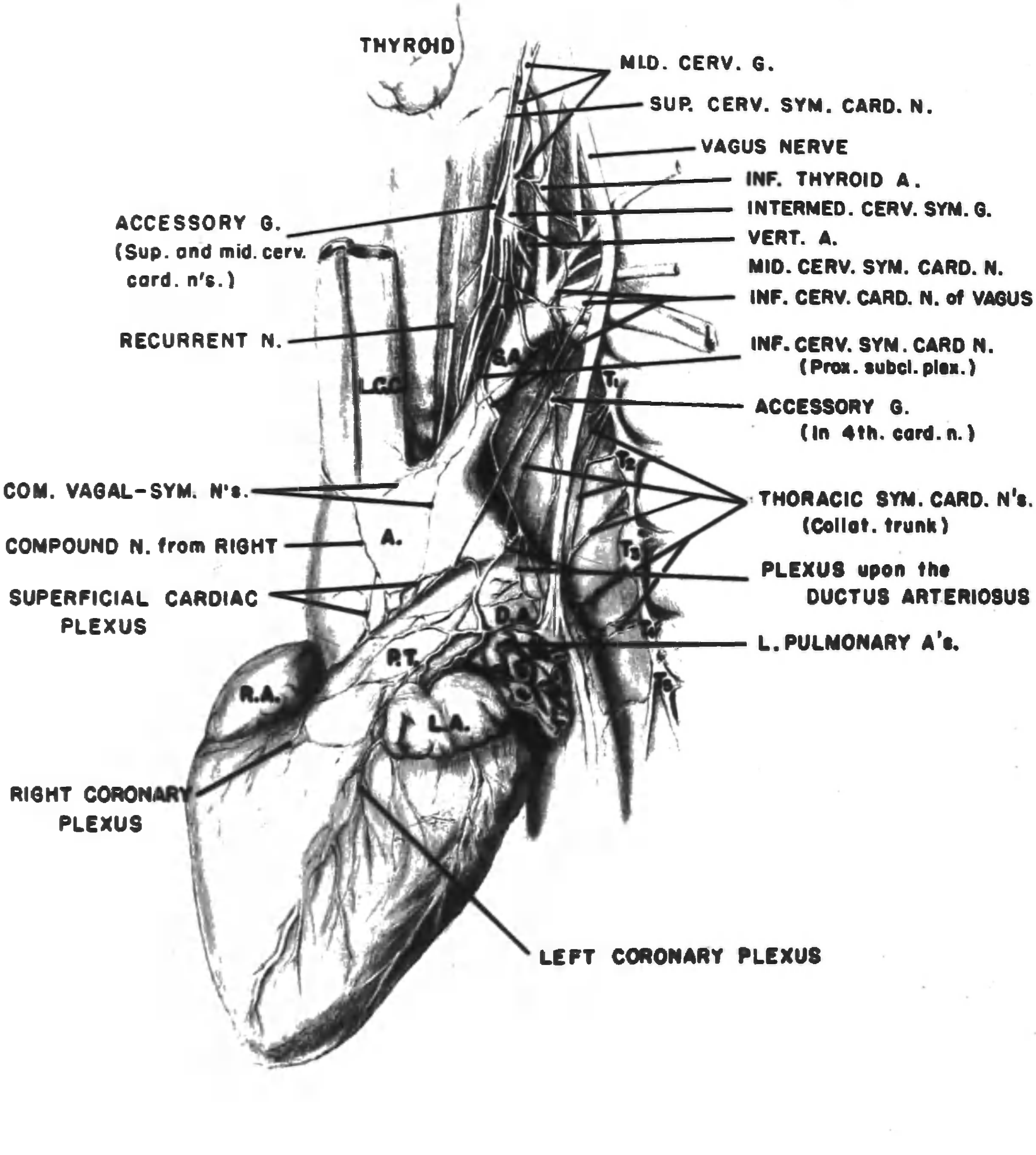
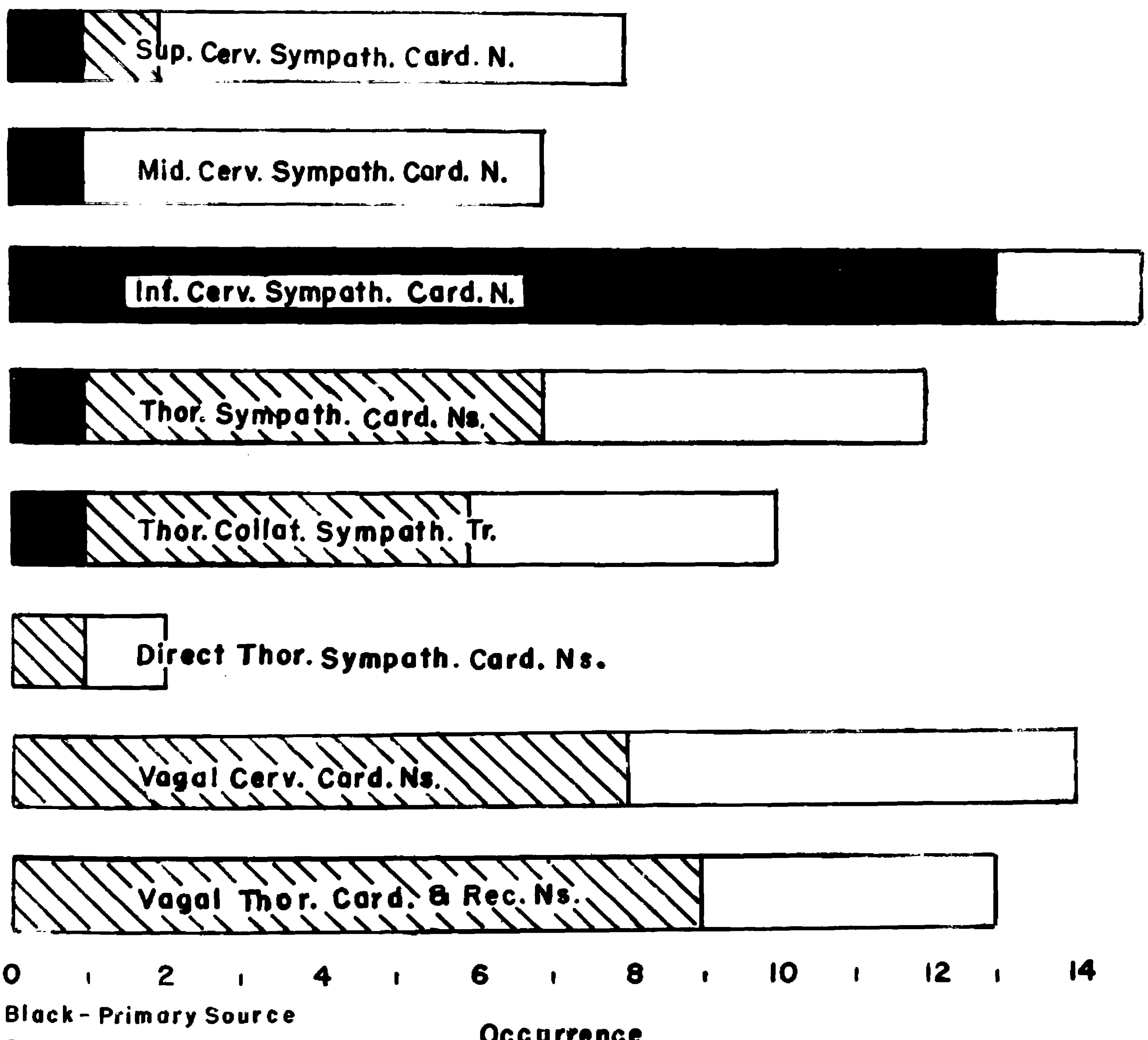

THYROID
MID. CERV. G.
SUP. CERV. SYM. CARD. N.
VAGUS NERVE
INF. THYROID A.
INTERMED. CERV. SYM. G.
VERT. A.
MID. CERV. SYM. CARD. N.
INF. CERV. CARD. N. of VAGUS
INF. CERV. SYM. CARD N.
(Prox. subcl. plex.)
ACCESSORY G.
(In 4th. card. n.)
THORACIC SYM. CARD. N's.
(Collat. trunk)
PLEXUS upon the
DUCTUS ARTERIOSUS
L. PULMONARY A's.
ACCESSORY G.
(Sup. and mid. cerv.
card. n's.)
RECURRENT N.
COM. VAGAL-SYM. N's.
COMPOUND N. from RIGHT
SUPERFICIAL CARDIAC
PLEXUS
RIGHT CORONARY
PLEXUS
LEFT CORONARY PLEXUS
L.C.C.
S.A.
A.
D.A.
P.T.
R.A.
L.A.

Figure 10

Contributory Nerves of the Ductus Arteriosus



Black - Primary Source
Cross Hatched - Strong
Clear - Weak

Figure 11

fibers to the ductus originated from the common cervical cardiac nerve on the left, formed essentially from the superior and middle sympathetic nerves and the cervical cardiac branches of the vagus. Most of the nerves to the ductus from the common nerve appeared to be derived from the middle cervical sympathetic cardiac nerve, but the possibility of contributions from the other components could not be eliminated. In the second case, dissection 15, the ductus received most of its innervation from thoracic sources, especially from the cardiac nerves of the second and third ganglia.

The proximal subclavian plexus, formed by the inferior cervical sympathetic cardiac nerve on the left side, most frequently gave rise to the nerves which supplied the ductus arteriosus (Figs. 1, 9, 10, 12, 13, 15, 16). Branches on the posterior and lateral surface of the left subclavian artery near its origin descended to the superior border of the aortic arch, crossed its anterior and lateral surface, and formed a plexus in the adventitia of the ductus. In dissection 6, however, a single nerve reached the ductus from the proximal subclavian plexus on the anterior surface of the left subclavian artery (Fig. 9). When the proximal subclavian plexus was poorly developed, the nerves passed directly to the ductus from the inferior cervical or stellate ganglion.

The most frequent source of sympathetic fibers to the ductus next was the upper three thoracic cardiac nerves, most frequently from the second and third segments of the thoracic trunk, although a branch from the stellate ganglion, in addition to the inferior cervical cardiac nerve from that ganglion, was also frequently observed. The nerves followed the intercostal vessels, passing anterior to the aorta, traversed the aortic plexus, and reached the ductus at its union with the aorta. These nerves were neither as constant nor as large as those from the inferior cervical sympathetic cardiac nerve.

Extreme development of the thoracic sympathetic cardiac nerve contribution to the ductus was observed in dissection 15 (Fig. 14). A large branch reached the ductus from the third thoracic ganglion. Several additional small twigs from the lower portion of the stellate ganglion, corresponding in this instance, to the first and second thoracic ganglia descended along intercostal arteries in the first and second interspaces to the aorta and ductus as described above.

Occasional filaments passed to the ductus from the superior and middle cervical sympathetic cardiac nerves. In one specimen the superior nerve made a noteworthy contribution through a communication with the proximal subclavian plexus. In all other cases, contributions from this nerve were small or doubtful and reached the ductus through the superficial cardiac plexus.

The branches of the vagus nerve to the ductus arteriosus were relatively few and small compared to those of the sympathetic. Vagal branches reached the ductus from the superficial cardiac plexus. Fibers of the vagus which formed a plexus in the adventitia of the aortic arch occasionally could be traced to the distal portion of the ductus. Fibers were also encountered passing from the vagus proper and the recurrent nerve as it passed around the lower border of the ductus. Occasionally a large nerve from the superficial plexus looped across the anterior surface of the ductus and at first appeared to be the major source of its fibers (Figs. 1, 16, and 17). Upon closer dissection, however, it was found that this loop contributed a very few small filaments to the ductal plexus.

The nerve branches to the ductus arteriosus formed a plexus in the adventitia of that vessel at its junction with the aorta. The contributing nerves either passed anterior to the aortic arch from the proximal subclavian plexus, crossed anterior to the aorta as branches of thoracic sympathetic cardiac nerves, or reached the ductus directly from the adjacent superficial cardiac plexus, vagus, or recurrent nerves. The smaller fibers of the plexus were, in general, directed proximally on the ductus to ramify and lose themselves in its adventitia. Other branches, somewhat larger, continued proximally into a plexus on the pulmonary trunk (Figs. 9, 10, 12, 13, and 14). Occasionally a rather large nerve on the inferior and lateral borders of the ductus and pulmonary trunk was formed by a regrouping of the nerves of the plexuses on those vessels. The larger branch, mentioned above, from the superficial cardiac plexus, which looped anterior to the ductus, often joined the nerve just described and together they proceeded to the left coronary plexus.

Although these larger nerves gave small filaments to the ductus, they were less intimately associated with the adventitia of the vessel than was the intrinsic plexus.

The ductus in two specimens had undergone the initial stages of anatomical obliteration. The plexus of nerves upon the ductus in these instances was still visible in the adventitia. Although the size of the ductus had been materially reduced, the component nerves supplying it showed no obvious changes except that their arrangement was morecompact and had the appearance of being incorporated, for the most part, into the superficial cardiac plexus.

DISCUSSION

Sympathetic Trunk

The results of the present investigation are in general agreement with the classical representation of the sympathetic trunk in the cervical and upper thoracic regions. Certain slight variations are probably characteristic of the fetal condition. Although numerous investigators have used fetal material in similar studies, few have made comparisons with adult material. Matsui ('25a and b) and Naatanen ('47) have presented systematic studies of the cervical and thoracic trunk in the newborn. The differences between fetal and adult sympathetic trunks, pointed out by these investigators and supported by the present observations, involve the position and relations of the ganglia, such as the short, stout interganglionic trunks in the thoracic region of the fetus.

In agreement with Matsui ('25b) we found that the superior cervical ganglion of the fetus was in a relatively high position, rarely extending below the second cervical vertebra. Its intimate connection with the nodose ganglion of the vagus and communications with spinal nerves is also confirmed, although no communication with the 6th cervical nerve, mentioned in his report, was observed.

Our observation of several ganglia between the superior and inferior cervical ganglia agrees with Matsui who found as many as 5 separate ganglionic enlargements in that position. He termed these the intermediate ganglia, but it was apparent that he made this term synonymous with middle cervical ganglia. They were found opposite the 6th and 7th cervical vertebrae and were divided into high and low types respectively. The high type appears to correspond with our middle cervical ganglion with respect to the spinal nerve communications, but was less frequently noted by Matsui (61%) than in the present study (86%).

The low type of " intermediate" ganglion of Matsui appears to be identical with our intermediate ganglion, both as to position, opposite the 7th cervical vertebra, and frequency, 84% in the former and 83% in the present study. These observations agree with the original description of the intermediate cervical ganglion by Jonnesco ('23) as well as with Hovelacque ('27) and Lazorthes and Cassan ('39). It was not always present as described by the latter, but might have been represented by a portion of the inferior cervical ganglion.

Lazorthes and Cassan represented the intermediate ganglion as the perivascular portion of the common cervicothoracic ganglion with the ansa subclavia and the ansae vertebrales joining the different portions of the larger ganglion. The present study agrees with these authors that the intimate relationship between the intermediate and inferior cervical ganglia is a fairly constant feature, but the writer believes that the former should be treated as an entity. It agrees also that the trunk is constantly split to enclose the vertebral artery. The origin of the ansa subclavia from the intermediate ganglion occurred in 62% in this study, whereas, Lazorthes and Cassan considered it to be always present.

This study agrees with Matsui and others (Siwe, '26, Pick and Sheehan, '46, and Jamieson et al, '52) that the intermediate ganglion most frequently communicates with the 5th, 6th, and 7th cervical spinal nerves. The significance of spinal nerve communications as criteria for identification of sympathetic ganglia in the cervical region is open to question. It has been observed that the spinal nerve communications of the classically described cervical ganglia may overlap as much as two segments. In addition, the vertebral nerve or plexus, which has its primary origin from the inferior cervical ganglion, ascends with the vertebral artery and is distributed as high as to the 4th cervical nerve (Christensen et al, '52). Branches to the vertebral plexus from the intermediate ganglion were present in 23% which does not entirely support the contention of Lazorthes and Cassan ('39) and Mitchell ('53) that this is a constant feature of the ganglion.

Exception is taken to the views of Axford ('29), Pick and Sheehan ('46), and Jamieson et al ('52) that this ganglion is a displaced portion of the middle cervical ganglion. Their interpretations were based on the spinal nerve communications of the ganglion which, as pointed out, are unreliable criteria and do not explain the frequent communications between the intermediate ganglion and the 7th cervical spinal nerve. The intimate association in the interganglionic trunk, the perivascular ansae, and common spinal nerve communications indicate that it would be more appropriate to link it with the inferior than the middle cervical ganglion, although it should be recalled that in the full term fetus the intermediate cervical ganglion is usually a well defined, separate ganglion and should be treated as such.

Mitchell ('53), on the basis of its intimate association with the vertebral artery, has called this ganglion the vertebral ganglion. This designation tends to exclude the ganglion from the cervical sympathetic chain and overemphasizes its relationship to the vertebral artery. This term should be reserved for the small ganglia which are found within the plexus which ascends on that vessel as first described by Valentin (1841). Finally, if precedence is to be honored, the term used by Jonnesco should be maintained and confusion with the small ganglia occasionally occurring in the sympathetic rami (Wrete, '35) can be avoided by using the full term, intermediate cervical sympathetic ganglion.

Features of the inferior cervical ganglion or its representative in the stellate ganglion were observed to be essentially the same as classically represented. In the full term fetus, however, the inferior ganglion was always separated from the first thoracic ganglion by a slight constriction (see Matsui, '25 a).

Our observations on the thoracic sympathetic trunk are in agreement with those of Matsui ('25 a) and Naatanen ('47). The occasional fusion of adjacent ganglia and splitting of the interganglionic trunks have been observed in the adult, but the relatively short, stout interganglionic segments are apparently characteristic of the fetus, before they are lengthened by growth of the trunk. The spinal nerve communications of the thoracic sympathetic usually arose from the ganglia and joined the corresponding spinal nerves, although occasionally a ramus arose from the interganglionic trunk and passed to the spinal nerve above or below.

Superior Cervical Sympathetic Cardiac Nerve

The present study confirms, for the most part, previous accounts of this nerve and adds statistical data concerning various features. It is present in 90% of the specimens but only rarely (10%) is it relatively independent. In the majority of the specimens it is joined with the middle cervical sympathetic nerve to form a common trunk, which often consists of several parallel, intercommunicating nerves.

The site of its termination on the left side in the superficial cardiac plexus is confirmed. Fibers from this nerve often reached the deep cardiac plexus, however, and in one instance the entire nerve terminated in the latter. On the right, the converse was true, i.e., the nerve passed to the deep cardiac plexus in all instances, although occasional branches to the superficial cardiac plexus were noted. In a single instance the entire nerve on the right passed to the superficial plexus. The observation of the right nerve passing to the superficial plexus agrees with Mayer (1794). On the right, it was noted that this nerve often sends a large number of its fibers to the innominate artery at its bifurcation. These fibers, many of them possibly representing the corresponding nerve of the vagus, which communicates with the sympathetic nerve high in the neck, are probably concerned with the pressor-receptive function of this area in lower animals as outlined by Nonidez ('37) and Hammond ('41).

Although branches of the superior cervical sympathetic cardiac nerve pass to visceral structures in the neck, the observations of this study are not in agreement with those of Saccomanno ('43) that the cervical sympathetic cardiac branches were materially reduced by such branches. Indeed, if the nerve contained an accessory ganglion, it was often observed to be larger distal to the ganglion.

Middle Cervical Sympathetic Cardiac Nerve

Analysis of the relative frequency of this nerve and its communications is an essential contribution in this study. The nerve was found in all specimens and, in agreement with Scarpa (1794) and others, it could usually be aptly termed, the great cardiac nerve. In agreement with earlier writers we observed that the origin of this nerve was not dependent upon the presence of a middle cervical ganglion, but arose from the trunk at the usual site of the ganglion when that ganglion was lacking. At its origin and for a variable distance beyond, the nerve consisted of multiple nerves in approximately 60% of the specimens. In 52% a portion of the nerve was derived from the intermediate cervical ganglion. Such contributions were relatively small in our material, but Mitchell ('53) observed that it occasionally gave rise to the entire nerve.

The classical concept of the distribution of the middle cervical sympathetic cardiac nerve to the deep cardiac plexus was supported by this investigation, but it was observed that a portion of this nerve, often small, also reached the superficial cardiac plexus in 45% of the specimens. In 20% of the fetuses, fibers from this nerve were given to the adventitia of the large arteries at their origin from the aortic arch, but our impression is that these fibers are actually of vagal origin.

Inferior Cervical Sympathetic Cardiac Nerve

This nerve was constantly found and was usually represented by several nerves rather than a single nerve. These nerves frequently formed a plexus on the proximal portion of the subclavian artery, especially on the left. According to Lazorthes and Cassan ('39) the inferior sympathetic nerve constantly had its origin from the intermediate and inferior cervical ganglia, and the ansa subclavia, whereas, in this study only the root from the inferior cervical ganglion was constant. A root from the intermediate cervical ganglion was found in approximately 70% of the specimens and the root from the ansa in 28%, limited to the left side.

As mentioned, these roots form the proximal subclavian plexus more frequently (86%) and better defined on the left than the right (29%). The plexus has been ignored by most writers on the cardiac nerves although Hovelacque ('27) gives a rather complete description of the plexiform nature of the inferior cervical sympathetic cardiac nerve. It is also represented in the drawings of Scarpa (1794), although not mentioned in the text, and is also observed in the work by Kondratjew ('27). Lazorthes and Cassan ('39) emphasized the fact that the major portion of the inferior sympathetic nerve was posterior to the subclavian artery, a feature supported by this investigation, and refer to a " bandelette spirale de Guillaume" with an " external" relationship to the subclavian artery which apparently corresponds to the portion of the plexus on the lateral and inferior aspect of the artery.

Branches of the inferior sympathetic nerve on both sides, whether part of the proximal subclavian plexus or not, may send fibers to the superficial cardiac plexus, and all send at least a portion of their fibers to the deep cardiac plexus. On the right, the great majority of the fibers pass to the latter plexus, whereas, on the left, fibers to the superficial plexus are constantly found in addition to those to the deep cardiac plexus.

In a single dissection the presence of an anomalous right subclavian artery altered the course of the middle and inferior cardiac nerves. In this instance the right subclavian artery arose from the aorta distal to the left subclavian artery, ascended obliquely behind the esophagus and trachea, and crossed the first rib in an essentially normal situation. The fact that a portion of the middle and inferior cardiac nerves in this specimen followed the aberrant vessel to the deep cardiac plexus may be of particular significance. It suggests that the sympathetic nerves utilize the large vessels from the aorta to reach the heart. It also indicates that these elements do not pass to the heart until after the aortic arches have formed the adult pattern. If this were not so, the sympathetic nerves would probably have followed their normal course along the arch prior to its obliteration. In the same anomaly, the vagal cardiac nerves were unaffected, possibly indicating their earlier extension to the heart. This agrees with the work of Kuntz ('20) and Licata ('54) who note that the vagal elements are established before the sympathetics, but a questionable statement is made in the latter paper, that the sympathetic elements follow the vagal cardiac nerves. In the same specimen, the right superior cervical sympathetic cardiac nerve was isolated and passed entirely to the superficial cardiac plexus, possibly indicating that if the sympathetic nerves on the right were segregated, the contribution to the superficial cardiac plexus would be made by that nerve. This would agree with the observations of Mayer

(1794).

The nerve to the heart from the lower portion of the stellate ganglion, observed in this study, is probably the same as the 4th cardiac nerve of Valentin (1841) and the nervus cardiacus imus of Tandler ('13) and Rauber-Kopsch ('53). Because of its resemblance to, and communications with the thoracic cardiac nerves, in the present study it is considered as the cardiac nerve of the first thoracic ganglion.

Thoracic Sympathetic Cardiac Nerves

The results of this study agree, for the most part, with the features of the thoracic sympathetic cardiac nerves which have been presented in recent years. However, an inherent weakness in the previous descriptions of these nerves should be pointed out, namely, the failure to emphasize the presence of visceral branches of the thoracic sympathetic chain which pass into the mediastinum without going to the heart or the aorta. The distinction is difficult since the nerves pass into the mediastinum together, but the nerves which arise from the medial aspect of the thoracic sympathetic chain, while in large part destined for the heart or aorta, also contain fibers which pass to the pulmonic structures and esophagus. If the term thoracic sympathetic cardiac nerves is reserved for those nerves which actually reach the cardiac plexus, a picture considerably different from the one drawn by Saccomanno ('43) is seen. Even when all the nerves arising from the upper 6 thoracic ganglia were included as cardiac nerves, which is essentially true, the total number of these nerves was considerably less than observed by the author just cited. In the present study, the number of nerves on each side was observed to be approximately 10, whereas, Saccomanno indicated that 15 to 20 nerves were noted with a cross sectional area twice that of the cervical sympathetic cardiac nerves. Although no definite measurement of the cross sectional area of the nerves was made in the present study, after careful examination, the impression gained does not agree with the above cited findings. The origin of these nerves, primarily from the third and fourth ganglia, and the fact that the higher thoracic cardiac branches pass to the cardiac plexus, whereas, the lower branches first become incorporated in the aortic plexus are confirmed.

Intercommunications of Sympathetic Cardiac Nerves

The observation of numerous communications between adjacent sympathetic cardiac nerves agrees with virtually all previous investigations. In contrast, however, it has been possible in many dissections to trace the elements beyond the communications and to determine their distribution.

A common cervical cardiac nerve formed by the middle cervical sympathetic cardiac nerve and the major portion of the superior cervical sympathetic cardiac nerve was often (35%)

observed and agrees with observations of Perman ('24), Hovelacque ('27) and others. The inferior cervical sympathetic cardiac nerve, especially the left, was observed communicating with the other sympathetic cardiac nerves less frequently. When the nerve formed a plexus on the subclavian artery its only communication consisted of small branches joining the plexus from the other nerves. The nerve on the right more frequently joined or gave a portion of its fibers to the common trunk.

The communications between the thoracic sympathetic cardiac nerves on the sides of the upper three or four thoracic vertebral bodies are probably the same as the " akzessorische Nervengebilde" of Kondratjew ('26) who reported a collateral trunk in about one-third of his specimens. This includes a nerve which descends from the stellate ganglion (1st thoracic ganglion) and probably represents the fourth cardiac nerve which was described by Valentin (1841). Within this plexus or series of arches a collateral trunk is sometimes distinguished. It usually appears as a continuation of the fourth cardiac nerve or nervus cardiacus imus (Tandler '13) and was found in 40% on the left and 20% of the specimens on the right.

Accessory Ganglia Associated with Sympathetic Cardiac Nerves

A small ganglion such as those described by Valentin (1841) and Arnold (1851) was observed in the superior cervical sympathetic cardiac nerve in 40% of our specimens and its greater frequency at the junction of this nerve with other cardiac nerves was also observed.

Muller's ('12) description of the cells making up the ganglion of Wrisberg, and the junction of the superior cervical sympathetic cardiac nerve with the superficial cardiac plexus suggests the possibility that the small ganglia on this nerve represent small aggregates of nerve cells which were halted in their migration to the ganglion. The recent paper by Licata ('54), on the other hand, suggests that the ganglion of Wrisberg is derived from neuroblastic tissue which follows the inferior cervical cardiac branch of the vagus to the sub-aortic recess. It is probable, however, that the neuroblastic tissue continues to the heart wall to form the intrinsic cardiac ganglia, whereas the primordium of the ganglion of Wrisberg reaches that site by way of the sympathetic nerves.

A small accessory ganglion in the middle cervical cardiac nerve was noted in approximately one-half the specimens. This ganglion was found at the junction of several of the cardiac nerves, often in the common cervical cardiac nerve and probably corresponds to the one described by Arnold (1851).

A small ganglion observed in the left proximal subclavian plexus in 40% but none on the right, was associated with the inferior cervical sympathetic cardiac nerve.

The small ganglionic enlargements in the collateral trunk or plexus formed by the upper thoracic nerves in our observations support Kondratjew (* 26). The highest of these ganglia was noted at the junction of the nerve from the stellate ganglion with the collateral trunk, but probably does not represent the ganglion supremum of the last mentioned investigator, because the latter was described as appearing at the union of a branch from the middle cervical cardiac nerve with the collateral trunk. Additional ganglia of the collateral chain or plexus were noted in approximately 50% of the specimens and were located at points of junction of the cardiac nerves with the chain or with the adjacent cardiac nerves when only a plexus was observed. This collateral chain may represent an upward extension of the lateral chains of the prevertebral plexus associated with the abdominal aorta as described by Hartmann-Weinberg (* 26).

The importance of the accessory ganglia mentioned above is that they represent additional sites for the location of sympathetic postganglionic neurones which would not be removed when the ordinary sympathectomy, experimental or therapeutic, is performed.

Superior Cervical Cardiac Nerve of the Vagus

The cardiac nerves of the vagus were considered along classical lines with the establishment of a definite level, the 6th cervical spinal nerve, as a dividing point between its superior and inferior cervical cardiac branches.

The distinct superior cervical cardiac nerve of the vagus did not exist in the specimens studied but fibers representing this nerve, including all branches of the vagus to the heart arising above the division point mentioned above, joined the superior cervical sympathetic cardiac nerve in 64% of the specimens. Only 36% of these specimens demonstrated fair sized communications and it is more appropriate to consider the fibers a normal constituent of the superior cervical sympathetic nerve. The lack of an isolated superior cervical cardiac nerve of the vagus supports the previous report of Duncan ('30).

Inferior Cervical Cardiac Nerve of the Vagus

Below the 6th cervical spinal nerve the cardiac branches of the vagus retain greater individuality and are designated the inferior cervical cardiac nerves. It was noted that the higher the origin of the nerve, the more likely was its communication with the sympathetic cardiac nerves. Such communications occurred in approximately 50% of the specimens on the left side and in 75% on the right. The difference in the two sides is probably related to the distribution of the majority of the nerves on the left to the superficial cardiac plexus. On the right, the nerve is frequently associated with the common cervical cardiac nerve which passes to the deep cardiac plexus.

On both sides filaments to the adventitia of the aortic arch or the large vessels arising from it may represent fibers of pressor receptor function supporting in part, contentions by Schumacher ('02), Perman ('24) and Duncan ('30).

Thoracic Cardiac Nerves of the Vagus

On the left side, the cardiac nerves were observed arising from the vagus nerve as it entered the thoracic cavity in 36% of the specimens, from the nerve as it crossed the aorta in an additional 36%, and from the recurrent nerve in 20% of the specimens. The first type terminated with the inferior cervical cardiac branches and probably represents a portion of the latter nerve which is carried into the lower cervical region when growth and extension of the trunk take place. The lower two types may be grouped together since their course and termination is the same. Both types from the vagus proper are ignored in the literature and the statement is made in most texts that the vagus on the left side does not have cardiac branches.

On the right, however, cardiac branches from the vagus within the thorax were constantly found and averaged 2.6 nerves which were divisible into those which arose from the vagus proper and those which arose from the recurrent nerve. Although communications between the cardiac branches of the recurrent nerve and the sympathetic occurred, the branches of the vagus proper usually passed as relatively isolated strands directly to the deep cardiac plexus. These observations correspond with those classically held regarding the nerves on this side.

Vago-Sympathetic Intercommunications

Certain features apparently influence the frequency and degree of communication between vagal and sympathetic elements which occurs in virtually all of the specimens. One of these is the distance between the origin of the nerve and its termination. That is, when a nerve has an extended course, such as the superior cervical cardiac nerve, its communications are more frequent. The middle and inferior cervical, and thoracic cardiac nerves of both types show correspondingly fewer communications as their length decreases. Another feature is the intervention of the subclavian artery between vagal and sympathetic elements. Thus, those sympathetic cardiac nerves which arise behind or below the subclavian artery are physically separated from the vagus or its branches and are less able to effect communications with it. In the thoracic region, this separation is complete and no communications between vagal and sympathetic thoracic cardiac nerves exist.

The presence of the numerous communications between the various nerves mentioned above conditions any interpretation that can be made in experimental studies in which those nerves are stimulated or sectioned in order to determine their distribution. In a sense, this study is in agreement with Swan (1830) who considered the cardiac plexus to extend into the cervical region by virtue of the numerous communications between the cervical cardiac nerves. On the other hand, if enough specimens are examined and if careful dissection is made, the individual characteristics of most of the cardiac nerves can be established.

Superficial Cardiac Plexus

The superficial cardiac plexus was found to conform, for the most part, with classical descriptions, although certain features of the plexus may profitably be reanalyzed. The plexus has been described as occupying the interval between the aortic arch and the ligamentum arteriosum (ductus arteriosus) and pulmonary trunk. However, Valentin (1841) included the nerves which crossed anterior to the aortic arch (extrapericardial) and those anterior to the ascending aorta and pulmonary artery (intrapericardial). This, linked with the presentations of Arnulf ('39, '49, and '50) and Hantz ('51) describing a preaortic plexus consisting of nerves passing anterior to the aortic arch, and supported by the findings of the present study, indicates that the superficial cardiac plexus should be defined as including all those fibers on the same plane anterior to the aortic arch, the descending aorta, the pulmonary trunk and the ductus arteriosus.

The plexus so defined is divided into three major portions according to its relationship to the structures mentioned above. The portion of the plexus corresponding to the classical description is designated as the central portion. The nerves anterior to the aorta, or any portion thereof, are considered the preaortic portion and those upon the ductus arteriosus and the pulmonary artery were considered to be the lateral or preductal portion of the plexus.

In addition to classically described sources, i.e., the left superior cervical sympathetic cardiac nerve and the left inferior cervical cardiac nerve of the vagus, the middle and inferior cervical sympathetic cardiac nerves on the left side contributed fibers to the superficial cardiac plexus, the former through its communications with the superior sympathetic nerve and the latter by its contributions to the ductus arteriosus. Scattered references to these contributions have been made in the literature (Sappey, 1852, Jaques, '02, and Arnulf, '39).

In some instances, branches of the thoracic sympathetic cardiac nerves reach the superficial plexus by their contribution to the ductus arteriosus. This supports the report of Kuntz and Morehouse ('30).

The contributions to the plexus from the vagus, in addition to the inferior nerve described above, include those branches of the vagus arising high in the thorax and from the superior cervical nerve by its communications with the corresponding sympathetic nerve.

The superficial cardiac plexus frequently (86%) receives a nerve, or nerves from the right side, most frequently of compound origin and only once, in the specimen with an anomalous right subclavian artery, being derived from a single source, the superior cervical sympathetic cardiac nerve. This feature of the superficial cardiac plexus seems to be recognized in most French writings on this subject but ignored in the English and German.

In contrast to Mitchell's ('53) opposition to separation of the cardiac plexus into superficial and deep portions, this study indicates that such separation is feasible and that considerable facility is afforded the descriptions of the cardiac nerve terminations by this division. Certain portions of the latter author's work would have been clarified if such a division had been used.

More recently, Licata ('54) describing the 9 week human embryo, termed this plexus the trunco-conal plexus. This term seems inadvisable because it includes the nerves on the deep surface of the aorta and pulmonary trunk previously considered part of the deep cardiac plexus.

Most of the nerves from the superficial plexus pass to the heart between the pulmonary trunk and the aorta continuing, at the base of the latter, as the right coronary plexus. In the enlarged concept of the plexus, however, the branches on the anterior aspect of the ascending aorta are occasionally observed joining the right coronary plexus. On the anterior and lateral aspect of the pulmonary trunk, some of the fibers constituting the superficial cardiac plexus pass around the inferior border of that vessel to join the left coronary plexus. The nerves which arise high on the left pass to the right coronary plexus, whereas, those from the left with lower origins eventually reach the left coronary plexus. Fibers which reach the superficial plexus from the right continue to the right coronary plexus.

Deep Cardiac Plexus

This study is in accord with earlier investigations but certain variations or modifications of previous descriptions of this plexus are suggested. Most of the fibers of the cardiac nerves reach this plexus with exception of the left superior cervical sympathetic cardiac nerve and the left inferior cervical cardiac nerve of the vagus, but occasionally these nerves do send branches to this plexus.

Limiting the plexus peripherally is an arbitrary matter and one which presents certain difficulties. Swan (1830), for example, considered the plexiform cervical cardiac nerves to be upward continuations of the cardiac plexus. In our study, however, the outer curvature of the aortic arch was used as its peripheral limit. It is found on the anterior aspect of the tracheal bifurcation, posterior to the arch of the aorta, and limited inferiorly by the right pulmonary artery. These observations agree with most previous studies. An additional feature emphasized by the present study, however, is the fact that the nerves extending from the cervical region pass behind the aorta with relatively few communications until they appreach the right pulmonary artery, then forming a noteworthy plexus which is oriented along the superior border of that vessel.

Division of the deep cardiac plexus into two portions has been suggested by previous investigations (Cruvielhier, 1845, His, 1891, Gegenbauer, '03 and Perman, '24). In the latter study, division is accomplished by an upward continuation of the transverse pericardial sinus, the aortic recess. In the light of the observations made in the present study, however, this statement must be modified to note the portions are continuous at the left border of the aortic recess. The nerves passing anterior to the recess extend toward the heart with the great arteries and join the coronary plexuses especially the left. These nerves are more frequently from the left with a branch from the right usually joining them.

The nerves which extend to the heart posterior to the aortic recess are from the right in largest part, and, are essentially the thoracic cardiac branches of the vagus. These branches pass almost exclusively to the right atrium at the base of the superior vena cava. In this situation they are adjacent to the pacemaker of the heart (sinoatrial node).

The nerves which pass posterior to the transverse sinus proper include branches from both sides which extend to the posterior aspect of the atria between the pulmonary veins.

The superficial and deep cardiac plexuses were observed communicating in three areas. One of these is on the right of the ascending aorta where occasional communications take place between the fibers on its anterior surface and the plexus passing down its posterior surface. Another, and strongest, is located between the aortic arch and the ductus arteriosus or pulmonary trunk. The third is at the lateral and inferior border of the ductus arteriosus and the pulmonary trunk. Although the communication with the central portion of the superficial cardiac plexus has been emphasized in previous investigations, the other communications have been ignored.

A large nerve crossing the ductus arteriosus or the pulmonary trunk represents the third type of communication referred to above. It was noted to be of variable composition and probably corresponds to one represented in the plates of Scarpa's work (1794) which crosses the ligamentum arteriosum. Arnulf ('39) described a nerve, derived from the nerves of the preaortic plexus, which descended on the pulmonary trunk and was designated " le nerf principal du coeur" . It winds inferior and lateral to the pulmonary trunk, sends a few branches to the left coronary plexus and joins the deep cardiac plexus on the posterior aspect of the pulmonary trunk. Other fibers of this nerve extend posterior to the transverse pericardial sinus, forming a slight ridge in the posterior wall of the sinus designated the pericardial fold of Marshall or the plica nervina atrii sinistra (Worobiew, '28). The fibers which pass posterior to the sinus pass to the heart through a reflection of pericardium representing the venous mesocardium as suggested by His (1891) and Perman ('24), and are distributed to the posterior aspect of the atria and ventricles.

Ductus Arteriosus

The observations of this investigation confirm the inference made by Boyd ('37 and '40) and Kennedy and Clark ('41 and '42) that the lower cervical and upper thoracic portions of the sympathetic trunk are the sources for sympathetic nerves to the ductus arteriosus. It is further shown that the most significant source is the left inferior cervical sympathetic cardiac nerve which arises from a ganglionic complex of the sympathetic trunk at the superior aperture of the thorax. This nerve, which is relatively free from communications with other cardiac nerves, forms a plexus on the proximal portion of the left subclavian artery which gives rise to one or two well defined branches which cross anterior to the aortic arch and ramify on the surface of the ductus arteriosus. When this nerve or plexus is small, a correspondingly small contribution is given to the ductus.

Additional sympathetic fibers to the ductus arise from the sympathetic trunk adjacent to the major source and vary in strength inversely to the contribution of the latter. These are most frequently observed arising from the second and third thoracic ganglia, whence they traverse the collateral chain, cross the lateral aspect of the descending aorta, and reach the ductus at its junction with the aorta. These fibers might correspond to those observed by Kuntz and Morehouse ('30) as passing to the superficial cardiac plexus. In a single instance, the primary nerve to the ductus was from a common superior and middle cervical sympathetic cardiac nerve, and, consequently, may have contained fibers from either or both of these. Contributions from the latter source, however, are probably insignificant.

Most of the vagal fibers pass to the ductus arteriosus either directly or by way of the superficial cardiac plexus, in either case being derived from the inferior cervical cardiac nerve. Small branches from the vagus and the recurrent nerve pass to the ductus as they are applied to its lateral aspect. In lower animals, the principle source of vagal nerves to the ductus is the aortic depressor nerve which does not exist per se in man as shown by Duncan (' 30) and confirmed in these studies. However, if the inferior cervical cardiac nerve is considered to represent, in part, the aortic depressor nerve of man, and this is not without justification, the findings of the present and previous studies are comparable. Licata (' 54) mentioned fibers to the ductus from the inferior nerve of the vagus in the description of a heart of a 9 week human embryo. In the same paper the close association of neuroblastic tissue, thought to give rise to the ganglion of Wrisberg of the adult, to the ductus was described and the suggestion made that " it may be concerned in regulation of its (the ductus) caliber" . No support to this concept is offered from the present study. Although branches to the ductus sometimes arise from the central portion of the superficial cardiac plexus, the site of the neuroblastic tissue, their numbers and size does not indicate a particularly close nervous connection. In several instances the central portion of the superficial cardiac plexus was entirely dissociated from the ductus in so far as nervous communications were concerned.

The size of the plexus upon the ductus varies, but in all instances the component nerves give rise to smaller branches which can be traced short distances into the wall of the ductus. The larger bundles of fibers are limited to the more superficial layers of the adventitia.

No interruption of the plexus occurs as the pulmonary trunk is approached, but regrouping of some of the nerves occurs and the trunk or trunks thus formed continue proximally on the pulmonary artery, perhaps representing " le nerf principal du coeur" of Arnulf (' 39). It is recognized, therefore, that only a portion of the nerves which form the plexus upon the ductus actually terminate there. It is observed also that the plexus upon the pulmonary trunk gives small filaments to that structure.

Following the initial stages of obliteration of the ductus, the plexus upon it was somewhat compressed and appeared more closely associated with the superficial cardiac plexus. No evidence of degeneration of the plexus was grossly visible at this stage but the ductus had not long been closed when these observations were made. Takino and Watanabe (' 37) found no degeneration of sensory (vagal ?) elements in the wall of the obliterated ductus (ligamentum arteriosum) but no study has considered the motor (sympathetic ?) elements.

The fate of the latter nerves upon obliteration of the ductus remains a question.

This study does not conflict with the experimental findings of Kennedy and Clark ('42) which indicate that nervous control is not required for the closure of the ductus at birth. However, the presence of a well defined sympathetic nerve plexus distributing fibers to the ductus arteriosus indicates further physiological examination in order to establish or refute its functional significance.

SUMMARY

The autonomic nervous system of the cervical and upper thoracic region of 15 full term human fetuses is described.

1. Sympathetic nerves to the ductus arteriosus pass from the left inferior cervical sympathetic cardiac nerve by way of the plexus on the proximal portion of the subclavian artery. Additional fibers are contributed to the ductus by thoracic cardiac nerves, particularly those from the 2nd and 3rd thoracic ganglia.

2. Vagal nerves to the ductus are derived from the inferior cervical and thoracic cardiac nerves, some of the fibers passing directly, others by way of the superficial cardiac plexus.

3. The ductal plexus distributes fibers to the wall of the ductus and the pulmonary trunk and, winding about the inferior border of the latter, passes to the left coronary plexus.

4. The superior cervical sympathetic cardiac nerve occurs in 90%, is rarely independent, with almost constant high vagal communications. The middle cervical sympathetic cardiac nerve is always found, is usually larger, and consists of multiple strands. The inferior cervical sympathetic cardiac nerve is constant, but varies in size. It is usually composed of multiple nerves which form the proximal subclavian plexus, especially on the left (85%).

5. The thoracic cardiac sympathetic nerves, usually 10 on each side, from the upper 6 thoracic ganglia, especially the 2nd, 3rd, and 4th. A nerve from the lower part of the stellate ganglion

(1st thoracic) probably corresponds to the 4th cardiac nerve of Valentin. These nerves usually form an accessory chain or plexus on the lateral surfaces of the upper thoracic vertebrae.

6. An intermediate cervical sympathetic ganglion was observed in 83%, was usually closely associated with the inferior cervical ganglion, and may be considered a usual component of the cervical sympathetic trunk.

7. Accessory ganglia associated with the sympathetic cardiac nerves are observed in approximately 50%.

8. The superior cervical cardiac nerve of the vagus usually exists as a communication with the superior sympathetic cardiac nerve. The inferior cervical cardiac nerve of the vagus is constant, the primary source of vagal cardiac fibers, and originates at the level of the subclavian artery. Thoracic cardiac nerves of the vagus are more numerous on the right but are frequently found on the left.

9. Communications between vagal and sympathetic cardiac nerves are most frequently observed in the upper cervical region, less frequently in the lower cervical, and are absent in the thoracic region.

10. The cardiac plexus was divided along classical lines into superficial and deep plexuses. The former consists of the cardiac nerves on a plane anterior to the aortic arch, and is separated into preaortic, central, and preductal portions. It receives the left superior cervical sympathetic and left inferior cervical vagal cardiac nerve,

but also receives fibers from other cardiac nerves, especially the left inferior cervical sympathetic cardiac nerve. A nerve from the right, of indeterminate origin, is a frequent contributor (86%) to this plexus. The deep cardiac plexus is small and circumscribed with its center along the superior border of the right pulmonary artery. It is separated into two portions by the pericardial sinuses, one portion anterior and small, the other posterior and large. These freely communicate on the left border of the aortic recess but are completely separated by the transverse pericardial sinus.

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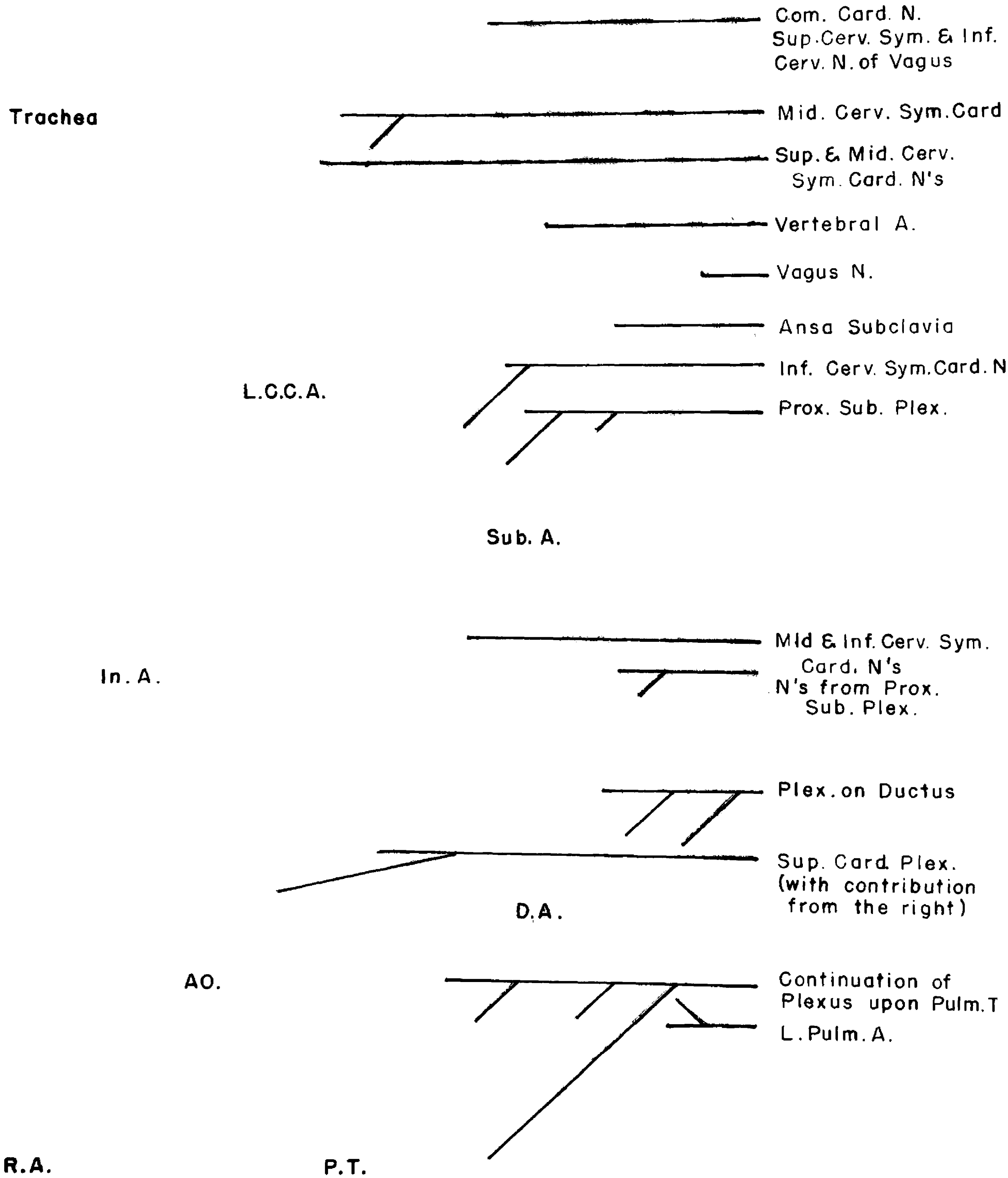
Com. Card. N.
Sup.Cerv. Sym. & Inf.
Cerv. N. of Vagus
Trachea
Mid. Cerv. Sym. Card I
Sup. & Mid. Cerv.
Sym. Card. N's
Vertebral A.
Vagus N.
Ansa Subclavia
Inf. Cerv. Sym. Card. N
L.C.C.A.
Prox. Sub. Plex.
Sub. A.
Mid & Inf. Cerv. Sym.
Card. N's
In. A.
N's from Prox.
Sub. Plex.
Plex. on Ductus
Sup. Card. Plex.
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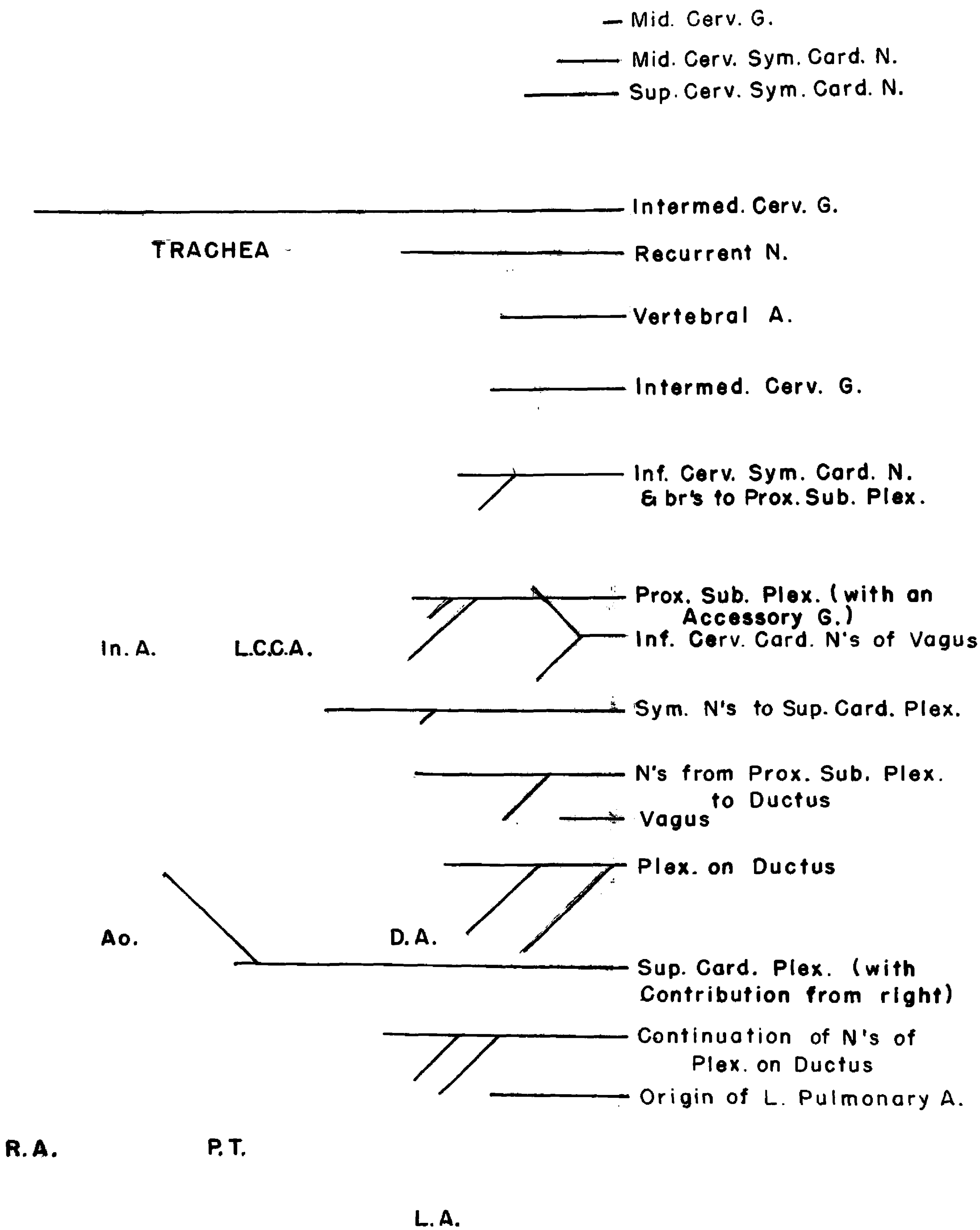
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Recurrent N.
Vertebral A.
Intermed. Cerv. G.
Inf. Cerv. Sym. Card. N. & br's to Prox. Sub. Plex.
Prox. Sub. Plex. (with an Accessory G.)
In. A.
L.C.C.A.
Inf. Cerv. Card. N's of Vagus
Sym. N's to Sup. Card. Plex.
N's from Prox. Sub. Plex. to Ductus
Vagus
Plex. on Ductus
Ao.
D. A.
Sup. Card. Plex. (with Contribution from right)
Continuation of N's of Plex. on Ductus
Origin of L. Pulmonary A.
R. A.
P. T.
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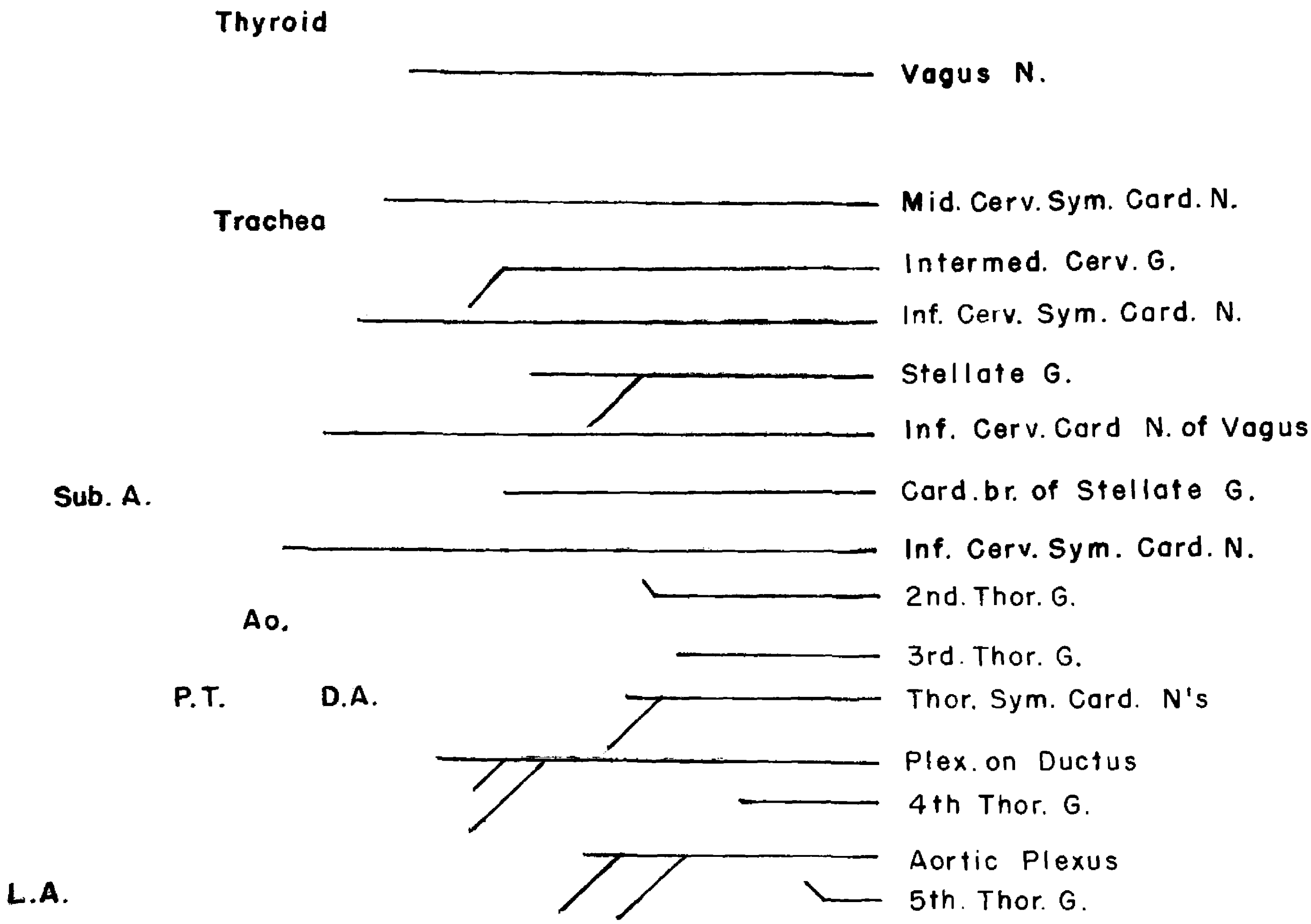
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Trachea
Intermed. Cerv. G.
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Stellate G.
Inf. Cerv. Card N. of Vagus
Sub. A.
Card. br. of Stellate G.
Inf. Cerv. Sym. Card. N.
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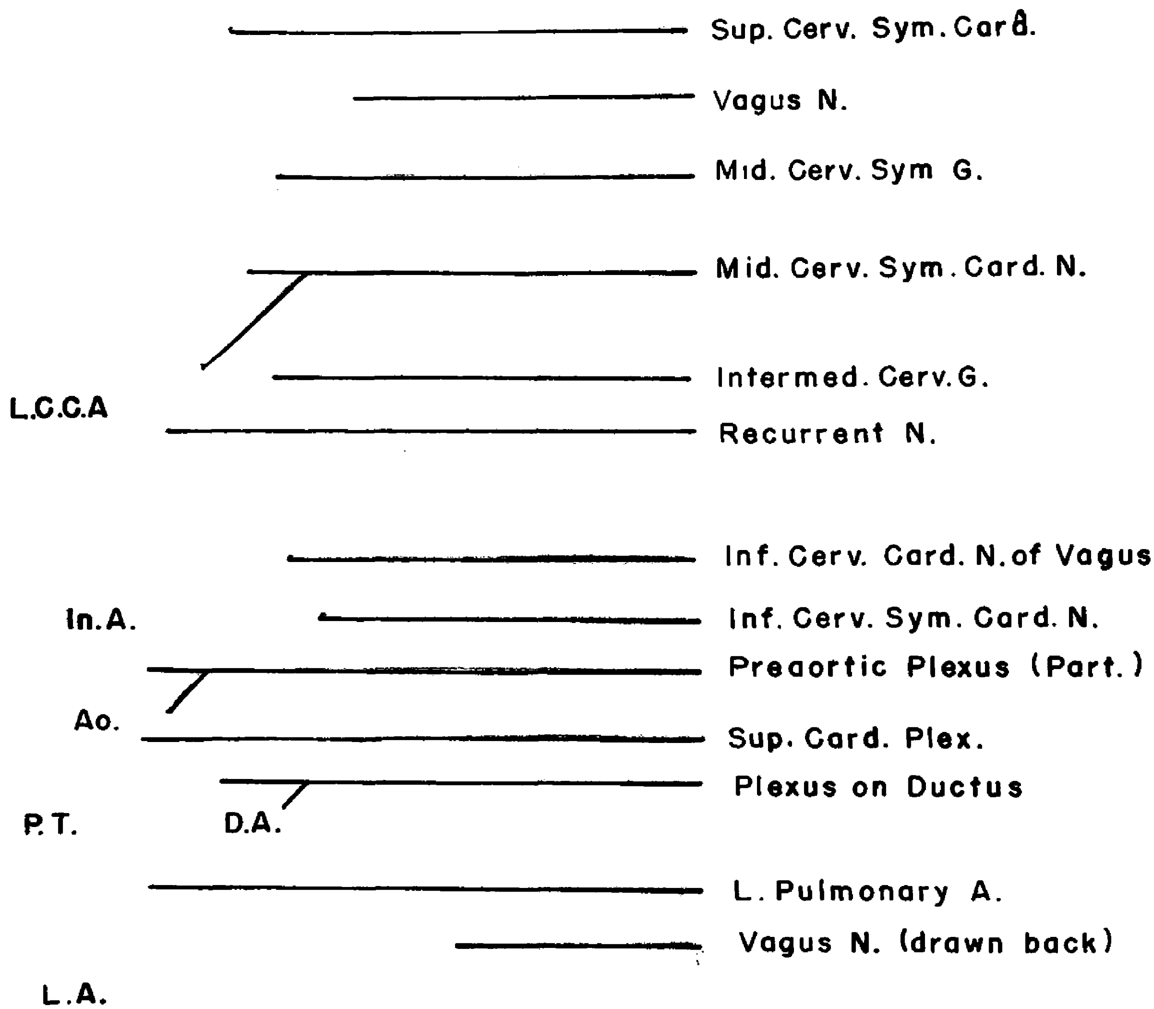
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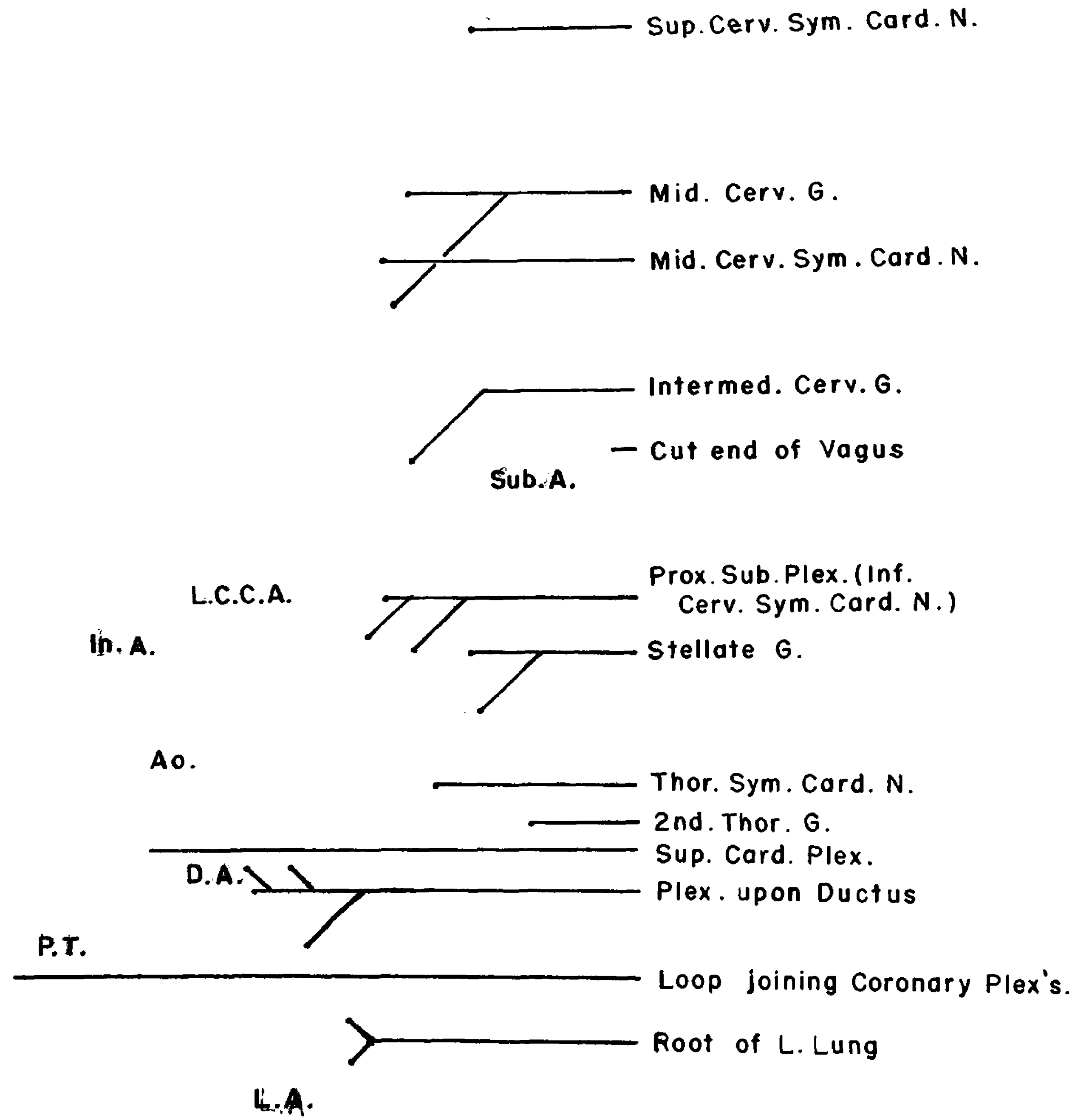
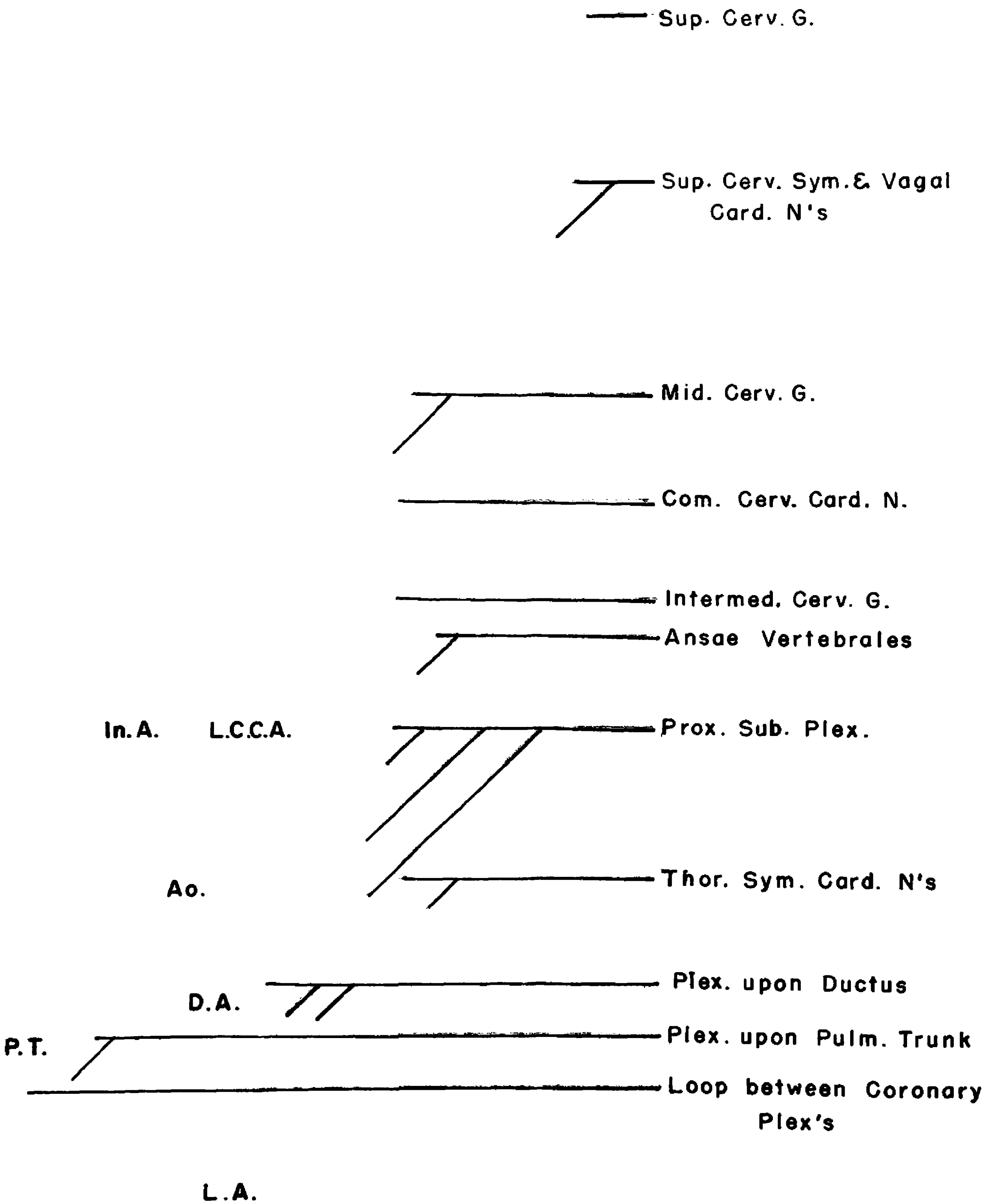
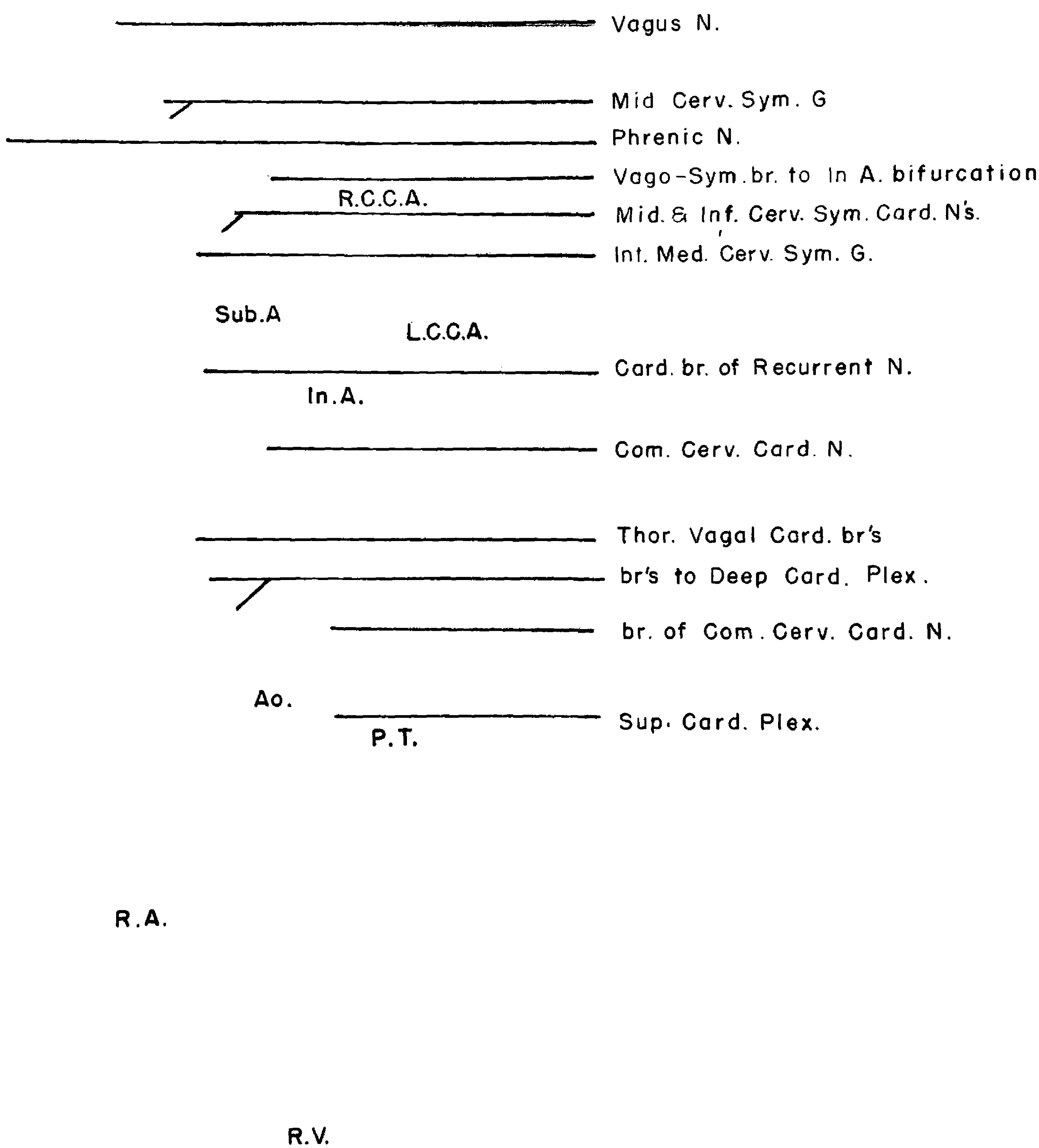
Vagus N.
Mid. Cerv. Sym G.
Mid. Cerv. Sym. Card. N.
Intermed. Cerv. G.
L.C.C.A
Recurrent N.
Inf. Cerv. Card. N. of Vagus
In.A.
Inf. Cerv. Sym. Card. N.
Preaortic Plexus (Part.)
Ao.
Sup. Card. Plex.
Plexus on Ductus
P.T.
D.A.
L. Pulmonary A.
Vagus N. (drawn back)
L.A.



Sup. Cerv. Sym. Card. N.
Mid. Cerv. G.
Mid. Cerv. Sym. Card. N.
Intermed. Cerv. G.
Cut end of Vagus
Sub. A.
L.C.C.A.
Prox. Sub. Plex. (Inf. Cerv. Sym. Card. N.)
In. A.
Stellate G.
Ao.
Thor. Sym. Card. N.
2nd. Thor. G.
Sup. Card. Plex.
D.A.
Plex. upon Ductus
P.T.
Loop joining Coronary Plex's.
Root of L. Lung
L.A.


Sup. Cerv. G.
Sup. Cerv. Sym. & Vagal Card. N's
Mid. Cerv. G.
Com. Cerv. Card. N.
Intermed. Cerv. G.
Ansae Vertebrales
In. A.
L.C.C.A.
Prox. Sub. Plex.
Ao.
Thor. Sym. Card. N's
D.A.
Plex. upon Ductus
P.T.
Plex. upon Pulm. Trunk
Loop between Coronary Plex's
L.A.



Vagus N.
Mid Cerv. Sym. G
Phrenic N.
Vago-Sym. br. to In A. bifurcation
R.C.C.A.
Mid. & Inf. Cerv. Sym. Card. N's.
Int. Med. Cerv. Sym. G.
Sub.A
L.C.C.A.
Card. br. of Recurrent N.
In.A.
Com. Cerv. Card. N.
Thor. Vagal Card. br's
br's to Deep Card. Plex.
br. of Com. Cerv. Card. N.
Ao.
Sup. Card. Plex.
P.T.
R.A.
R.V.

TABLE NO. I. INTERMEDIATE CERVICAL SYMPATHETIC GANGLION

Dissection		Description		Relationships				Spinal Nerve Communications				Terminal Branches
No.	Side	Size in cm.	Shape	Vessels	Vertebral Levels	Inf. Cervical or Stellate G.	Middle Cervical Ganglion	C_5	C_6	C_7	C_8	
1	L	0.4 x 0.15	fused 2G.	no information	C7	intimate, doubled IGT	discrete fair size at C5-6	-	-	-	-	2 cardiac N's (1 separate & 1 with MCCSN
	R	0.2 x 0.2	small glob-ose		lower C6 upper C7	fused, or thick IGT between	2G., 0.2 cm. above 0.2 cm. dia.	-	-	1br.	-	-
2	L			not recorded								
	R	0.5 x 0.2	ovoid	-	lower C6 upper C7	IGT thick between	fair size 1cm. above	-	-	1 lg Br.	-	2 cardiac N's (1 separate & 1 with MCCSN)
3	L	0.6 x 0.15	elongate, 3 sm. G	IGT split to enfold Vert. A.	lower C6 upper C7	IGT split into 4 (1 large 3 sm.	separate, IGT split by Inf. T. A.	-	1br.	-	-	2 cardiac N's (1 to MCCSN & 1 to ICCSN)
	R	0.8 x 0.2	union of 3 sm. G	inf. to Inf. T.A., ant. med. Vert. A.	lower C6 upper C7	IGT split & enfolds Vert. A.	separate IGT split by Inf. T. A	1br. with C4	-	-	-	2 card. N's, brs. to MCCSN&ICCSN 1br. to Phren. N.
4	L	0.5 x 0.2	ovoid	med. to Inf. ant.-med. Vert. A.	C7	IGT short thick, com. br. C. Sp. N	joined by two trunks	com. br.	com. br.	com. br.	-	1 cardiac br. via Subclavian Plexus
	R	0.5 x 0.2	ovoid	ant. Vert. A., med. to Inf. T. A.	lower C6 upper C7	Ansa Sub. & single IGT	small G. at C5, IGT single	C4 br. only	-	-	-	2 card. N's to MCCSN&ICCSN, vascular brs.
5	L	0.7 x 0.35	large ovoid	ant. Vert. A., med. to Inf. T. A.	C7	Ansa Sub. & single IGT.	small G. at upper C6. 2 IGT	com. tr. of the se & C3&4		com. tr. with Br. of ICG.		weak card. br. to MCCSN & br. to Thyrocerv. Tr.
	R ?	0.2 x 0.4	flat wide G.	post. Sub. A. (some med. Vert.)	lower C7	thick IGT only part. separation	single IGT large MCG	-	-	1br.	-	1card. br. to ICCSN, Brs. to Sub. A. & Vessels
6	L	0.4 x 0.2	ovoid	ant.-med. to Vert. A. at origin	C7	Ansa Sub. & lg. & sm. IGT's (Vert. A	several (3) G. on Inf. T. A.	-	2 brs.	1br.	-	2 card. N's (MCCSN&ICCSN), Vert. br. & vasc. brs.
	R	0.2-0.3 diam.	round	ant.-med. to Vert. A. at origin	C7	intimate, double IGT & Ansa Sub	2 weak swellings at Inf. T. A.	-	1br. with ICG	-	-	ICCSN & MCCSN brs. to Vert., Sub. & Int. Mam. A's
7	L	0.2 in diam.	round	ant.-lat. to Vert. A.	C7	intimate thick IGT Ansa Sub.	elongate several G. fused	-	-	1br. with ICG	-	1card. N. with ICCSN, Vert. & Thyrocerv. A's.
	R	0.3 x 0.15	ovoid	ant. to Vert. A.	C7	thick IGT Ansa Sub. large.	definite G. lat.-sup. to Inf. T.	-	1br. IGT sup.	1br. IGT inf.	-	small br. to ICCSN, br. to Thyrocerv. Tr.
8	L	none per se, however, superior end of stellate ganglion characteristic										
	R	0.2 x 0.15	small ovoid	ant.-med. to Vert. A.	lower C6 upper C7	stout IGT doubled Ansa Sub.	small oval opposite Inf. T. A.	-	-	-	-	large br. to MCCSN, 1 br. to Int. Mam. A.
9	L	0.4 x 0.25	ovoid	ant.-med. to Vert. A. at origin	C7	double IGT (Vert. A.) Ansa Sub.	discrete G. post.-Inf. T. A.	1br.	1Br.	1Br. via V. A.	-	Brs. to both MCCSN & ICCSN vascular brs.
	R*	0.2 in diam.	round	ant. to Vert. A. at origin	C7	thick IGT loops Vert. A., Ansa	discrete G. inf. to Inf. T. A.	-	-	1br. with ICG	-	3 brs. (cardiac?) vascular Brs. (anom. Sub. A.)
10	L	0.2 in diam.	round	ant. to Vert. A. at origin	lower C6 upper C7	IGT double Ansa Sub. Sp. N. com.	weak G. inf. to Inf. T. A.	1br. with MCG	1br.	-	-	vascular brs. (Sub., Int. Mam. Thyrocerv.), card?
	R	0.4 x 0.15	2 G. fused oval?	ant.-Vert. A.-origin, med.-Inf. T	lower C7	IGT & Ansa Sub., Sp. N. com's	strong G. sup.-lat. to Inf. T. A.	-	-	2brs. with ICG	-	vascular brs., 3 cardiac brs. MCCSN & ICCSN
11	L	0.3 x 0.15	2 G. fused oval?	ant.-med. to Vert. A., med.-Inf. T	lower C6 upper C7	strong IGT doubled, Sp. N. com. Ansa	strong G. sup.-lat. to Inf. T. A	1br. with MCG	1br. with ICG	-	-	vascular brs., 2-4 card. brs. (ICCSN)
	R	0.15 x 0.1	small ovoid	ant.-med. to Vert. A. at origin	C7	double IGT Sp. N. communica	strong G. sup.-lat. to Inf. T. A.	1br. with MCG	3brs 1via ICG	-	-	vascular brs., 1 card. br. (ICCSN)
12	L	0.4 x 0.25	irreg. flat-tened	ant.-med. to Vert. A. med.-Inf. T	C7	intimate IGT stout Ansa Sub.	small G. sup. to Inf. T. A.	-	1br. with ICG	1br. with ICG	-	Card. br. (ICCSN) of IGT, vascular brs., esoph.
	R?	0.2 x 0.1	weak swell-ing	as the IGT loops med. to Vert. A.	C7	thick IGT loops Vert. A., Ansa	weak G. at level of Inf. T. A.	-	2brs	-	-	part of ICCSN
13	L	0.25 x 0.3	trun-cated pyram	ant.-med. to Vert. A. at origin	lower C6 upper C7	very thick IGT, Ansa doubled	small G. sup. to Inf. T. A.	-	2brs	1br. with ICG	-	most of ICCSN, vascular brs.
	R	0.2 in diam.	round	med. to Thyrocerv. Tr.	lower C6 upper C7	intimate IGT, Ansa Sub.	2 small G. at level of Inf. T. A.	-	brs. via V. A.	1Br.	-	vascular brs. forms ICCSN Vert. A. Plex.
14	L ?	?	lip of stell.	ant.-med. to Vert. A. at origin	C7	a portion of Stell. G.	strong G. post. to Inf. T. A.	-	1Br	1br.	-	vascular brs. Vert. A. Plex. card. br. (ICCSN)
	R	0.2 in diam.	round	ant.-med. to Vert. A. at origin	C7	thick IGT (2), Ansa	elongate G. post. Inf. T. A.			1br. via ICG	1br via ICG	1 delicate card. br.
15	L ?	0.3 x 0.2	ovoid	ant.-med. to Vert. A.	lower C6 upper C7	intimate slight con-strict IGT	none	weak br.	2 Brs	1br.	-	cardiac brs. (MCCSN&ICCSN) vascular brs.
	R	0.2 x 0.2 x 0.3	round	ant.-lat. aspect of Vert. A.	upper C7	doubled IGT, Ansa	weak or non-exist-ent	1br.	1br.	1br.	-	br. to MCCSN, 2brs. to Vert. Plex. vascular brs.

TABLE NO. 2. SUPERIOR CERVICAL CARDIAC SYMPATHETIC NERVE(S)

Dissection		Origin	Course					Communications		Terminations
			Relations				Structural Features i.e., Ganglia, etc			
No.	Side		Com. Car. Art.	Inf. Thy. Art.	Sub-clavian Art.	Innominate Art.		Vagal	Sympathetics	
1	L	S.C.G. 2 rts IGT$_{sg}$ 3 rts	post.	ant.	ant. med.	-	G. ant. to aorta	Several	Left M.C.C.S.N.	Sup. Card. Plex. Left ant. Pulm. Plex.
	R	absent per se						(?)		
2	L	not recorded								
	R	not recorded								
3	L	1 rt. IGT$_{sg}$ 1rt. SL-X	post.	ant.	post. med.	-	1 G. with M.C.G. twig	Only at origin	2 brs. MCG. 1 br. I.C.G.	Deep Card. Plex.
	R	1 rt. S.C.G.	post.	ant.	med.	ant. & post.	2 small G. at N. union	With 2 Ns at C_6	brs. M.C.G.	Base of Innom. A. Deep Card. Plex. twig to Thyr. Plex.
4	L	2 rts. IGT$_{sg}$ IGT lower	post.	ant.	ant.	-	G. at union of roots	crossing Sub. A.	M.C.C.S.N.	Sup. Card. Plex. Ductus Arteriosus
	R	rt. S.C.G. (?)IGT$_{amg}$	med.	ant.	post. & med.	post.	-	-	-	Deep Card. Plex. directly
5	L	absent per se							(?)	
	R	junction SCG & IGT	post.	ant.	ant.	ant.	plexiform	2 brs. at Sub. A.	both C.C.Ns on Innom. A.	Deep Card. Plex. Sup. Card. Plex. (?)
6	L	1rt S.C.G. 1rt IGT$_{sg}$	post. med.	ant.	ant.	-	1 small G. at C_7	via ant. Sub. Plex.	M.C.C.S.N. as brs MCG	Sup. Plex. to plex. on Pulm. A. & D.A. (?) twig to Thyr. Plex.
	R	small rt. IGT$_{sg}$	med.	ant.	ant.	post.	small G.	terminal with l. Rec.	M.C.C.S.N. I.C.C.S.N.	Deep Card. Plex.
7	L	1 lg., 1sm. rts S.C.G.	post. med.	ant.	ant.	-	plexiform	1 br. high, 1 br. term.	br. of M.C.C.S.N.	Sup. Plex. & brs. on med. side P.A. & D.A.
	R	1rt. S.C.G.	post. med.	ant.	ant.	post. med.	splits, med. part with G.	2 twigs of C.C.Ns.	M.C.C.S.N. I.C.C.S.N.	Deep Card. Plex. twigs to Thyr. Plex.
8	L	1 rt. S.C.G.	post. med.	ant.	ant.	-	G. union M.C.C.S.N.	1 br. X 1 br. SL-X	2 brs. of M.C.C.S.N.	3 brs. to Deep Card. Plex. weak br. Sup. Plex.
	R	1 large rt. S.C.G.	post. med.	ant.	ant. & post.	med.	winds on Innom. A.	2 brs. X	Common Tr. terminally	Bifurcation of Innom. A., Deep Card. Plex. Thyr. & Trach. brs.
9	L	3 rts. S.C.G.	post.	ant.	ant.	-	small G. at branching	with X	M.C.G. & M.C.C.S.N.	via Common Tr, Sub. plex. to Sup. Plex.
	R*	1 rt. S.C.G. 1 rt. IGT$_{sg}$	post.	ant.	ant.	none	direct	3 brs. with X	twig from M.C.G.	Sup. Card. Plex. Com. Car. A. at base
10	L	2rts. S.C.G. 1rt. IGT$_{sg}$	post.	ant.	ant.	-	small G. at aortic arch	terminally C.C.Ns of X	(?) M.C.C.S.N.	Brs. to Com. Car. A. 2brs. to Sup. Plex. twigs to Thyr. Plex.
	R	2rts. S.C.G.	post.	ant.	ant. & post.	lat. & ant.	small G. at origin	very slight	(?) M.C.C.S.N.	Sup. Card. Plex. Deep Card. Plex. (?) Thyr. & laryng. brs.
11	L	1 rt. IGT$_{sg}$	post.	ant.	ant. & post.	-	split, small N.	lat. part card. brs.	med. part M.C.C.S.N.	Sup. Card. Plex., brs. to Com. Car., Thyr.
	R	2rts. SCG	post.	ant.	ant. & post.	lat.	splits midway	br. to X high.	1 br. com. tr. M.C.C.S.N. & I.C.C.S.N.	Deep Card. Plex., brs. to Innom. A., Sup. Card. Plex. (?)
12	L	1rt. S.C.G.	post.	ant.	ant. & post.	-	G. as joins other S. Ns.	at origin	joins M.C.C.S.N.	2 brs. to Deep Card. Plex., Innom. & Sub. As.
	R	2rts. S.C.G.	post.	ant.	ant. & post.	post. lat.	forms Com. Tr.	1br. SL-X 2brs. X	Common Tr. M.C.C.S.N.	via Common Tr. to both Card. Plexuses twigs to Thyr. Plex.
13	L	2rts. S.C.G.	post.	post.	med.	-	trifurcates about C_6	several brs. to X	M.C.C.S.N. I.C.C.S.N.	base of Com. Car. A. Deep Card. Plex.
	R	absent per se						via brs. to X ?		
14	L	2rts. S.C.G. rt. IGT$_{sg}$	post. lat.	ant.	med.	-	doubled or plexiform	brs. at origin X & SL-X	fused with M.C.C.S.N.	Mainly Deep Card. Plex. twig to Sup. Plex.
	R	1br. S.C.G. joins SL-X (?)	med.	ant.	med.	ant.	anomalous course, by thyroid	1 br. X & 2brs. SL-X (leave)	-	adventitia of Com. Car. and Innom. As.
15	L	4brs. S.C.G. 1br. IGT$_{sg}$	post. med.	ant.	med.	-	split, med. & lat.	med. part 1br. SL-X (leaves)	both parts M.C.C.S.N.	mainly Deep Card. Plex., Sup. Plex., Brs. to bases of Sub. & C.C.
	R	1rt. S.C.G.	post.	ant.	ant. & post.	ant. & post.	isolated nerve	with X in neck	br. to Com. N. post. to Sub. A.	Deep Card. Plex. & adventitia of Innom. A.

TABLE NO.3. MIDDLE CERVICAL CARDIAC SYMPATHETIC NERVE(S)

Dissection		Origin	Course					Communications		Terminations
			RELATIONS				STRUCTURAL FEATURES i.e., ganglia, etc.			
No.	Side		Com. Car. Art.	Inf. Thy. Art.	Sub-clavian Art.	Innominate Art.		Vagal	Sympathetics	
1	L	1 rt. MCG 1rt. Int. CG	post.	ant. inf.	ant. & post.	-	G. at union with SCCSN	twig to left recurrent	SCCSN & ICCSN	essentially in the Deep Cardiac Plexus Sup. Card. Plex. (?)
	R	1rt. MCG 1rt. from 3rd CSN	post.	ant.	post.	post.	portion from C_3 with X.	fibers to X noted	terminally	Deep Cardiac Plexus
2	L	not recorded				-				
	R	2rts MCG 1rt. Int. CG	post.	-	post.	post.	large nerve	with left recurrent	twig ICCSN	terminates in Deep Cardiac Plexus
3	L	1rt. IGTbmg 1rt. Int. CG	post.	inf.	post.	-	G. at union with SCCSN	SL-X	Common tr. SCCSN br. of I. -	Deep Cardiac Plexus
	R	2rts. MCG 1rt. Int. CG	post.	ant.	ant.	lat.	2-3 small G. at union of roots	with C.C. brs. of X, recurrent	twig of ICCSN all term.	Deep Cardiac Plexus Sup. Card. Plex. (?)
4	L	1rt. MCG 1rt. IGTbmg	post. lat.	inf.	post.	-	plexiform	left recurrent	SCCSN ICCSN via Sub. P.	essentially to Deep Cardiac Plexus
	R	1rt. IGT at site MCG 1rt. Int. CG	post. med.	-	post.	post. lat.	separate N's, lower with G.	left recurrent	(?) fibers ICCSN	Common Carotid A. Deep Cardiac Plexus
5	L	2rts. IGT (MCG) 1rt. Int. CG	post.	ant.	post. &ant.	-	plexiform with sm. G.	3 brs. to left recurrent	part of ICCSN	Both Sup. and Deep Cardiac Plexuses
	R	3-4rts. from MCG and IGTbmg	post.	ant.	post. &ant.	post. lat.	individual brs. not a single N.	1br. with CCN's of X	2brs. to SCCSN	adventitia of Subclavian, Com. Carotid & Innom. A's, Deep Plex.
6	L	3rts. MCG 1rt. Int. CG	post. lat.	1br. ant.	ant. post.	-	G. at union of roots & Com. Tr.	1br. to L. recurrent & br. of X	Com. Tr. SCCSN br. of I. -	possibility that both plexuses get brs.
	R	1br. from Int. C.G. 1br. MCG	post. lat.	-	post.	post. lat.	separate N's to Com. Tr. &L. Rec.	Br. of MC G. to Rec. 1br. X	unites with SCCSN	Deep Cardiac Plexus Sup. Card. Plex. (?)
7	L	6rts. from MCG	post. lat.	3rts. ant.	ant. post.	-	rts. form 3 main N's 1 with G.	via SCCSN	SCCSN & Sub. Plex.	Deep Cardiac Plexus Sup. Card. Plexus(?)
	R	4rts. MCG	post. lat.	2rts. ant.	post.	post. med.	rts. unite in G. with SCCSN	br. to recurrent from G.	at small G. with SCCSN	Deep Cardiac Plexus twig to Sup. Plex (?)
8	L	2 large brs. of MCG	post. lat.	inf.	post. med.	-	rts. unite in G. with SCCSN	via SCCSN	SCCSN	Deep Cardiac Plexus br. to ant. of Aorta
	R	2brs. IGT (MCG) & 1br. Int. CG	post. lat.	1br. ant.	post.	en-folds	Com. Tr. with SCCSN	CCN's of X by Com. Tr.	SCCSN by Com. Tr.	Deep Cardiac Plexus
9	L	2brs. MCG 2brs. Int. CG	post.	2brs. ant.	post.	-	G. (?) at union of rts.	none	Com. Tr. brs. of S. &ICCSN	Deep Cardiac Plexus
	R	1rt. MCG	post. med.	-	post.	to trachea	simple N. with communicat.	with CCN's of X	see text	(anomalous course) Deep Cardiac Plexus
10	L	1rt. IGT-bmg	post.	-	post.	-	simple N.	twig to left recurrent	slight	Deep Cardiac Plexus
	R	1rt. MCG 1rt. Int. CG br. to Rec.	post.	ant.	post. / ant.	post. lat.	G. in lg. br. with SCCSN	MCG to recurrent 1br. of X	SCCSN	Deep Cardiac Plexus Sup. Card. Plex. (?)
11	L	2rts. MCG weak rt. of IGTbmg	post. lat.	ant.	post. med.	-	2 separate nerves	none	part of other CCSN's	especially Common Carotid A, Deep Card. Plex.
	R	3rts. of MCG	post.	ant.	post.	post. lat.	brs. form Com. Tr.	CCN's of X & L. Recurrent	Com. Tr. SCCSN ICCSN	br. to Sup. Card. Plex. Deep Cardiac Plexus
12	L	1rt. MCG 2rts. IGT-bmg	post.	ant.	post.	-	G. at union with SCCSN	via SCCSN (?)	Com. Tr. SCCSN	Deep Cardiac Plexus
	R	1rt. MCG	post.	-	post.	post. / ant.	Com. Tr.	via twigs in SCCSN	Com. Tr. SCCSN	Deep Cardiac Plexus Sup. Card. Plex. (?)
13	L	1rt. MCG 1rt. IGT-bmg	post.	ant. post.	sup. med.	-	doubled	2 twigs from X	SCCSN brs. of I. &Int. CG	Deep Cardiac Plexus adventitia of Com. Carotid and Aorta
	R	1Rt. MCG (small) 1rt. IGTbmg	post.	ant.	post.	post.	moderately simple N. G.	X proper in neck, recurrent	ICCSN from Int. CG	Deep Cardiac Plexus
14	L	1Rt. immed. above MCG	post. lat.	loops ant.	med.	-	strong N. small G. at origin	via com. with SCCSN	Com. Tr. SCCSN	Deep Cardiac Plexus twig to Sup. Plex., br. to ant. aorta
	R	2 weak brs. MCG elongate	post.	-	post.	post.	very weak	none	none	Deep Cardiac Plexus
15	L	2rts. IGT-bmg &Int. CG	post. lat.	en-fold	sup. med.	-	splits, 5 brs. G. at origin	br. from X at Sub-clav. A.	Com. Tr. SCCSN, br. of ICCSN -	Deep Cardiac Plexus with twig to Sup. Card. Plex.
	R	2rts. IGT-bmg, 1rt. Int. CG	post. lat.	en-fold	ant. & post.	post. lat.	doubled	twig to recurrent	near term. with ICCSN	Deep Cardiac Plexus weak filament to Sup. Card. Plex.

TABLE NO. 4. INFERIOR CERVICAL CARDIAC SYMPATHETIC NERVE(S)

Dissection		Origin	Course			Communications		Termination
			RELATIONS		Structural Features i.e., ganglia, etc			
No.	Side		Sub-clavian Art.	Innomi-nate Art.		Vagal	Sympathe-tics	
1	L	3rts. from Stell. G.	essenti-ally post.	-	roots form 1 N.	with C.C. N's of X	MCCSN TCSN's	Deep Cardiac Plexus Ductus arteriosus Sup. Card. Plex. (?)
	R	1rt. from Stell. G.	post.	post. & lat.	single N.	none	Com. Tr. TCSN's	Deep Cardiac Plexus
2	L	1rt. from Stell. G.	post.	-	quite weak N.	with X proper	none	Deep Cardiac Plexus Ductus arteriosus
	R	not recorded						
3	L	3rts. Stell. G. 1rt. Int. CG	plexus mainly post.	-	plexiform but 1 main N. formed	none	twig to Com. Tr.	Deep Cardiac Plexus Ductus Arteriosus
	R	1rt, ICG 1rt. Int. CG	post. ? inf.	post. & lat.	essentially 1 N.	CCN's of X	SCCSN MCCSN	Deep Cardiac Plexus Sup. Card. Plex. (?)
4	L	2rts. Stell. 1rt. Ansa Subclavia	post. & inf.	-	plexiform 3 brs. Sub. Plex.	none	MCCSN TCCSN	Deep Cardiac Plexus Ductus Arteriosus Via Sub. Plex. weak
	R	1rt. Stell 1rt. Int. CG	post. & inf.	post. & lat.	single N.	twig to recurrent	terminal	Deep Cardiac Plexus
5	L	1rt. Stell 1rt. Ansa Subclavia	plexus on prox. portion	-	2 main portions	recurrent	MCCSN via Sub. plex.	Ductus Arteriosus Deep Cardiac Plexus
	R	2rts. ICG 1rt. Int. CG	post. & sup.	post. & lat.	splits & reforms	(?)	twig to Com. Tr.	Deep Cardiac Plexus
6	L	2rts. Int. CG. 2rts. Stell.	plexus on prox. portion	-	G. in Sub. plexus	CCN's of X	twig from Com. Tr. TCSN's	Deep Cardiac Plexus Ductus Arteriosus
	R	2large rts. ICG 1rt. Int. CG	post. & inf.	post. & inf.	discrete N. then Com. Tr.	CCN's of X & recurrent	Com. Tr.	Deep Cardiac Plexus
7	L	2Rts. Stell. 1rt. Int. CG	post.	-	separate N's to term.	none	twigs to MCCSN & TCSNs	Deep Cardiac Plexus weak br. to Sup. Card. Plex. & Ductus Art.
	R	1rt. Stell 1rt. Int. CG	post. loop. ant.	post. & lat.	2 small N's with loop conn.	upper N. joined Tr. to br. X	SCCSN	bifurcation of Innom A. with Tr. Deep Cardiac Plexus
8	L	3rts. Stell 1rt. Int. C. G. (?)	plexus on prox. portion	-	4-6 fibers extensive with 2 G.	CCN's of X, br. recurrent	none	2brs. to Ductus Art. Deep Cardiac Plexus Sup. Card. Plexus
	R	2rts. of Stell. G.	post. & inf.	post. & lat.	relatively simple N.	part with C. br. of recurrent	part to Com. Tr.	Deep Cardiac Plexus
9	L	1 lg. Rt. of Int. CG 1rt. Stell.	post. & plexus prox.	-	main trunk with brs. looping A.	small br. of X into Sub. Plex.	2 twigs to Com. Tr.	Deep Cardiac Plexus Ductus Arteriosus
	R*	3rts. IGT-inf. Int. G. 2rts. Stell.	post. sup. post. inf.	anom. no Innom. present	all 5 rts. separate courses	none	none	Deep Cardiac Plexus via anomalous Artery Esophageal Plexus ?
10	L	2rts. IGT-as. or Int. C. G.	small plexus post. sup.	-	large N. with twigs Sub. Plex.	none	branch to SCCSN	Ductus Arteriosus Sup. Card. Plex., brs. to adventitia Sub. A.
	R	2 weak rts. Stell. G. Rt. Int. CG.	weak plexus prox.	post. & lat.	weak plexiform	none	none	weak brs. in wall of Sub. & Innom. A's. Deep Cardiac Plexus
11	L	2rts. Int. C. G. 3rts. Stell.	plexus prox. (post.)	-	1 main Tr. yielding brs. plex.	none	br. to 1st. TCSN	Deep Cardiac Plexus Sup. Card. Plex. Ductus Arteriosus
	R	1rt. Stell. 1rt. Int. C. G.	ant. sup. & post.	lateral	3 small N's independent	none	1br. to Com. Tr.	Deep & Sup. (?) Card. Plexuses & adventitia of Sub. & Innom. A's
12	L	1Rt. Int. C. G. 2rts. Stell.	plexus esp. post. & sup.	-	1 main Tr. with brs. to plexus	none	1 br. to TCSN's	Both Cardiac Plexuses Ductus Arteriosus
	R	2rts. Stell. 1 twig of Int. C. G.	post.	post. & lat.	2 N's not very strong	via Com. Tr. CCN's X	1 N. to Com. Tr.	Deep Cardiac Plexus Sup. Card. Plex. (?)
13	L	2Rts. Int. C. G., Ansa 1rt. Stell.	plexus mainly post.	-	3 main Trs. sup., ant. post. to A.	none	twig from MCG	Deep Cardiac Plexus Sup. Card. Plex. & Ductus Arteriosus
	R	2Rts. Int. C. G. clasp Vert. A.	post. & sup.	post. & lat.	2 main brs. elaborate courses	recurrent	1br. to Com. Tr.	Deep Cardiac Plexus Sup. Card. Plex. (?)
14	L	1 Large Rt. Int. CG, rts. Ansa & Stell.	heavy or dense plexus	-	Swollen as if ganglionic	none	small twig of MCG	Large contribution to both Card. Plex. & Ductus Arteriosus
	R	5rts. Stell (weak)	post. & inf.	post. & lat.	diffuse group of N's.	with CN's of recurrent	TCSN's	Deep Cardiac Plexus adventitia on ant. aspect of Innom. A.
15	L	1Rt. Int. CG, 2-3 rts. Stell	sup. weak prox. plex.	-	1 main br. & several strands	none	1 twig of MCG	Deep Cardiac Plexus weak brs. to Sup. Card. Plex. & Ductus
	R	1Rt. Stell. 1rt. Stell.	post. & inf.	post. & lat.	1 main br.	receives br. of recurrent	brs. to S&MC& TCSN's	Deep Cardiac Plexus Sup. Card. Plex. (?)

TABLE 5. THORACIC CARDIAC SYMPATHETIC NERVES

Dissection No.	Side	T 1	IGT T1-2	T 2	IGT T2-3	T3	IGT T3-4	T 4	IGT T4-5	T5	IGT T5-6	T6	Description and Distribution
1	L	1br.	-	1br.	1br.	2brs.	-	1br.	-	1br.	1br.	1br.	upper brs. with a br. of stellate form Collat. Tr. others to Aorta & Ductus
	R	1br.	-	1br.	-	1br.	-	1br.	-	(?) 1br.	-	(?) 1br.	upper 3brs., br. of Stell. G. form Collat. Tr. to Deep Card. & Aortic Plex's.
2	L	-	-	weak 1br.	-	weak 2brs.	weak twig	-	weak 1br.	weak 1br.	-	-	weak brs. which pass toward Aortic plexus but not possible to follow well.
	R	-	-	1br.	1br.	-	-	1br.	1br.	-	(?)	(?)	upper 3brs. converge to form a trunk (with a G.) joined by twig of Stell. G.
3	L	-	-	1br.	2-3 brs.	1br.	weak 2brs.	1br.	-	3brs.	-	(?)	upper 2-3brs. form plexus joined by br. of Stell. G. brs. to Aorta & Ductus A.
	R	1br.	-	1br.	1br.	1Br.	2brs.	1br.	weak 1br.	-	weak 1br.	weak 1br.	upper 4 N's form plexus, G. present. brs. to Deep & Aortic Plexuses. Collat. Tr?
4	L	1br.	-	1br.	-	2Brs.	1br.	-	1br.	-	1br.	1br.	Collat. Tr. formed, gets br. of Stell. G., send brs. to Ductus A. & Aorta
	R	1br.	1br.	3brs.	-	2brs.	-	2brs.	2brs.	1br.	1br.	2brs.	upper brs. plexiform with G. (?) brs. to Deep Card. Plexus, some to Azygos V.
5	L	2brs.	1br.	1Br.	1br.	3brs.	1br.	1br. 1Br.	-	1br.	1br.	2brs.	upper brs. plexiform, hint of Collat. Tr., brs. to plexuses, Deep, Aortic, Duct.
	R	1br.	-	1br.	1br.	3brs.	2brs.	2brs.	-	1br.	-	3brs.	relatively direct brs. to Deep and Aortic plexuses, upper brs. weak plexus
6	L	-	1br.	-	2brs.	-	1br.	1br.	-	1br.	-	2brs.	3arches, upper 2 united, G., Stell. G. br., Ductus & Aortic plexuses get brs.
	R	1br.	1br.	3brs.	-	1br.	2brs.	-	2brs.	-	1br.	-	relatively direct brs. to Deep Card. & Aortic plexus G. at union of adjacent N's
7	L	1br.	1br.	1br.	1br.	-	2brs.	2brs.	1br.	-	-	-	upper brs. form weak Collat. Tr. (G.) with br. Stell. G., Ductus & Aorta brs.
	R	weak 1br.	-	2brs.	1br.	1br.	none	1Br.	1Br.	3brs.	-	-	relatively direct brs. to Deep Card. Plex. (upper) and Aortic Plex. (lower brs.)
8	L	-	1br.	1br.	-	1Br.	-	weak 2brs.	2brs.	-	-	weak 1br.	weak nerves. brs. of T2 & T3 form loop yields brs. to Ductus & Aortic plexus
	R	1br.	-	1br.	1br.	1br.	1Br. 1br.	1br.	2brs.	-	2brs.	1br.	upper brs. form Collat. Tr. to deep and Aortic plexuses; part follow Azyg.
9*	L	-	1br.	2brs.	-	1Br.	-	1br.	-	weak 1br.	-	weak 1br.	br. of T3 to Aorta & Ductus A., main part of T2 & T3 to Deep & Aortic Plex's.
	R	weak 1br.	-	weak 1br.	weak 1br.	weak 1br.	2brs.	2brs.	-	weak 1br.	weak 1br.	-	relatively direct brs. to the Deep. Card. & Aortic Plexuses, use Azygos V. ?
10	L	1Br.	1br.	1br.	-	weak 1br.	weak 1br.	1br.	-	-	-	-	N's very weak, traced toward Aorta, some fibers probably into its plexus
	R	1br.	3brs.	-	weak 1br.	(?) no G.	weak 1br.	2brs.	weak 1br.	weak 2brs.	-	(?)	weak upper brs. form Collat. Tr. with small G. brs. to Deep & Aortic plexuses
11	L	2brs.	1br.	1Br.	-	2brs.	1br.	-	weak 2brs.	weak 2brs.	weak 1br.	-	upper brs. form arch or Collat. Tr. (G.?) brs. to Ductus & Aortic Plexus.
	R	weak 2brs.	-	4brs.	-	-	weak 3brs.	2brs.	-	-	-	-	weak contributions to the Deep Card. and Aortic Plexuses. few use Azyg. V.
12	L	1br.	-	3brs.	weak 1br.	-	3brs.	weak 1br.	weak 1br.	weak 2brs.	-	weak 2brs.	Collat. Tr. formed of br. of ICCSN & T1&T2 brs. Ductus & Aortic Plexus.
	R	weak 1br.	-	1Br.	weak 1br.	1Br.	-	1Br. 2brs.	(?) 1br.	weak 1br.	-	-	Strong nerves from T4 with inter communicat. to Deep Card. Plex.
13	L	weak 1br.	-	weak 1br.	weak 1br.	1br.	weak 1br.	weak 1br.	1br.	-	-	-	upper 3-4brs., with br. of Stell. G. form Collat. Tr. brs. to Ductus & Aorta
	R	weak 1br.	weak 1br.	2brs.	-	2brs.	weak 1br.	3brs.	-	weak 2brs.	-	weak 1br.	upper brs. pass to Deep Card. Plex., lower brs. to Aortic Plex. via Azygos. V.
14	L	1br.	-	2brs.	-	2brs.	-	1br.	1br.	-	1br.	2brs.	strong plexus or Collat. Tr. with br. of Stell. G. (G.) Ductus, Aortic & Deep.
	R	3brs.	none	2Brs	-	-	2Brs	1br.	1br.	2brs.	-	2brs.	Strong direct fibers to Deep & Aortic Plexuses
15	L	1br.	-	1br.	2brs.	-	1Br.	2brs.	-	2brs.	-	weak 1br.	upper brs. in Collat. Tr. (weak) with br. ICCSN along Aorta; Brs. Ductus & Aorta
	R	weak 1br.	-	1br.	-	1br.	-	1br. 1Br.	1br.	1br.	-	weak 2brs.	br. of T3 with br. of Stell. G., to Deep Plex. via Azyg. lower brs. direct Aorta

TABLE 6. VAGAL CARDIAC NERVES

Dissection		Cervical				Thoracic	
		Superior		Inferior			
No.	Side	Origin	Course & Termination	Origin	Course & Termination	Origin	Course & Termination
1	L	2brs. of X proper	communicate at origin with SCCSN and included in it	-	-	1br. ant. to aortic arch	passes with recurrent N. lat. to Ductus to Deep Plex.
	R			ant., inf. to the Sub. A.	passes inf., med. on lower border Sub. A., Deep Plex.	" several" brs. of X proper	direct to Deep Cardiac Plexus
2	L	not recorded					
	R	not recorded					
3	L	1Br. of SL-X	?	1Br. 1cm above Sub. A.	lat. & post. to Innom. A., commun. Sup. & Deep Card. Pl.	3brs. below recur. N.	all to Deep Card. Plex. strong brs.
	R	tiny brs. of X. go to SCCSN	with Sym. fibers to adventitia Aorta and Deep. Card. Plex.	3brs. ant. to Sub. A.	part to Common N. others direct to Sup. Plex. & Duct. ?	1br. of X at Rec. N's orig.	loops beneath and sends twig to Ductus then Deep Plexus
4	L	-	-	1Br. of X, at Sub. A.	joins SCCSN, brs. to aortic arch, Sub. A. & Sup. C. Plex.	-	-
	R	-	-	1Br. of X at 6th C. vert.	ant. to bifurcat. of Innom. A. brs. to it, Sup. & Deep Plex.	1Br. high 1br. low in Thor.	along post. lat. side of Innom. A. to Deep Card. Plexus
5	L	1br. of X proper, 1 br. SL-X	both brs. join Sym. Tr. & yielded as MCCSN?	1br. of X ant. to Sub. A.	brs. to adventitia of aortic arch, brs. to Sup. Plex., Duct.	1br. high 1br. low	high br. to SCCSN & Sup. Plex., low br. (weak) to Ductus
	R	3-4 brs. of X join Sym.	branch formed rejoins vagus (?)	3brs. sup. & ant. to Sub. A.	complex communications with Sym's both Plex's & Innom.	1Br. of X just below Rec.	post. lat. to Innom. A., joins other N's, Deep Plexus
6	L	(?)	twigs to Sym's (?)	2brs. sup. & inf. to Sub. A.	joins proximal Sub. Plex. brs. to both Plex's & Ductus	1br. 1cm below Sub. A.	joins N's of X mentioned above by ascending
	R	1br. of X (G.)	post. to C.C.A. & then ant. to Innom. joins complex.	1br., 1Br. both sup. Sub. A.	1br. to C.C.A., 1Br. joins plex. of all C. N's	2brs. of recurr.	descend post. lat. to Innom. A., brs. to Deep. Card. Plex.
7	L	1br. of X	joins SCCSN (br. of SCCSN rejoins X)	1br. at sup. edge of Sub. A.	direct to Sup. Card. Plex.	2small brs. of recurr.	Deep Card. Plexus Ductus Arteriosus
	R	very small br.	joins SCCSN	2brs. above Sub. A.	1 to SCCSN and 1 to adventitia of C.C.A.	1 large 2 small recurr.	all join and pass directly to Deep Card. Plexus
8	L	1br. of X 1br. of SL-X	both join SCCSN which forms loop with X lower	2brs. on sup. & inf. Sub. A.	1br. to Sub. Plex. 1Br. direct to Sup. Plex., Ductus?	1br. 1cm below Sub. A.	to Sup. Card. Plex. Ductus Arteriosus ?
	R	2brs. of X	1br. to Innom. bifurcation, 1br. to SCCSN	3brs. sup. to Sub. A.	1br. to SCCSN, 2brs. to Common Tr. lower in neck	2brs. of recurr. 1br. of X	Deep Card. Plexus
9	L	(?) brs. of X to Sym's	2brs. of SCCSN (rejoining?) pass to X.	1 large Br. of X Sub. A.	communication with Sub. Plex., to Sup. Plex. & Ductus	1br. of X 1cm above recurr.	loops beneath Ductus to reach Deep Card. Plex.
	R	(?) 1br. of X	joins SCCSN	2brs. 1cm above Sub. A.	complex, anomalous Sub. A., brs. to Deep Card. Plex.	3brs. of X (low)	direct to Deep Cardiac Plexus
10	L	-	-	1Br. sup. 1br. inf. Sub. A.	sup. br. to Sub. Plex. (Ductus?) 1br. to Sup. Plex., SCCSN	2brs. of X above recurr.	loops beneath Ductus to reach Deep Card. Plex.
	R	1br. of X midway in neck	joins SCCSN	1Br. 1cm above Sub. A.	br. to Sym. twig to Sup. Plex. rest to Deep Plex.	2Brs. of recurr. 1br. X	1Br. recurrent to Com. Tr. other direct to Deep Plexus
11	L	-	-	3brs. sup. 2brs. ant. to Sub. A.	sup. brs. to SCCSN lower brs. to C.C.A., SCCSN-Sup. Pl.	-	
	R	2brs. of X (G.)	joins SCCSN	1Br. ant. to Sub. A.	join Common Tr. with Sym's., br. to Sup. & Deep Plex.	2brs. of recurr. 1Br. of X	both to Deep Card. Plex., recurrent br. twig to Com. Tr.
12	L	1Br. of X(G.), 1 br. of SL-X	individual N. to C.C.A. and Deep Card. Plex.	1br. 1cm. sup., 1br. ant., Sub. A.	inf. br. to base of C.C.A. & Aorta, sup. br.-Sup. Plex.	2brs. of X at sup. aperture	both to Sup. Card. Plexus direct
	R	1small br. of X (G.)	joins SCCSN	2brs. ant. to Sub. A.	communicates with Common Tr. (Sym's) to Deep Plex.	1br. of recurr. 1Br. of X	both to Deep Card. Plexus
13	L	1br. of SL-X	joins SCCSN	1Br., 1br. ant. to Sub. A.	joins br. of MCCSN multiple terminal. brs., 1 to Sup. Plex.	1Br. of X midway in thor.	direct to Sup. Plex. and loop around Ductus Arteriosus
	R	-	-	3 small brs., ant. sup.-Sub.	all 3 communicate with Sym's which brs. to Innom. A.	2Brs. of recurr. 2Brs. of X	1br. of recurrent joins Sym's, all to Deep Card. Plexus
14	L	1br. of X (G.), 1br. X proper	unite and then join SCCSN, definite contribution	1Br. at sup. edge of Sub. A.	brs. to trachea & recurrent, main br.-Prox. Sub. Plex.	-	-
	R	1br. of SL-X (?)	with Sym. br. on post. lat. Thyroid to C.C.A. & Innom. A.	2brs. at 1cm. sup. to Sub. A.	1br. to Innom. A. 1br. with Sym's to Deep Card. Plex.	1br. of recurr. 2brs.-X	all to Deep Cardiac Plexus
15	L	see inf. cerv. card. N of X	-	1 large Br. mid. of neck	main portion to Sup. Card. Plex. 1br. to base C.C.A.	1br. of recurr.	to plexus upon Ductus Arteriosus
	R	1br. of X midway in neck	joins SCCSN (innominate A.)	1 weak br. ant. to Sub. A.	joins plexus at bifurcation of Innominate A.	1br. of recurr. 2brs.-X	direct to Deep Cardiac Plexus

TABLE 7. SUPERFICIAL CARDIAC PLEXUS

Dissection		Contributory Nerves								Description of Contribution(s) from the right	Description of Plexus proper
		Sympathetic				Vagal					
No.	Side	Sup. Cerv. Card.n	Mid. Cerv. Card.n	Inf Cerv. Card.n	Thor. Card. N.	Sup. Cerv. Card.n	Inf. Cerv. Card.n	Rec. Card. N.	Thor. Card. N.		
1	L	all	(?)	(?)	via ? Duct. Plex.	via SCC SN	abs.	-	abs.	No contribution from the right noted	of moderate size containing ganglionic mass. Fairly simple plexus. Classical position.
	R	-	-	-	-	-	-	-	abs.		
2	L	incomplete		via Duct. Plex.	-					none recorded	notation made in regard to the communications with the plexus upon Duct. Art.
	R	not recorded									
3	L	-	-	(?) Duct. Plex.	(?)	-	in part	-	abs.	Noteworthy branch from a Common Tr. on right. Bases obliquely lat. to Innom. A. to cross ant. to Aortic arch	Classical position communications with Plexus upon Ductus Art. Br. extends to Conus Art. Br. looping Ductus Art.
	R	via Com. Tr. ?	via R. Com. Tr. ?	via R. Com. Tr. ?	-	-	via R. Com. Tr. ?	-	-		
4	L	all	(?)	via ? Duct. Plex.	via ? Duct. Plex.	abs.	all	abs.	abs.	Contribution from branch of vagus just above Sub. A. Crosses innominate A. obliquely and ant. to aorta at A's orig.	Preaortic portion of moderate size & continuous. Linear appearing. Definite contribution to Ductus Plexus.
	R	-	-	-	-	abs.	? via In. A Plex.	-	abs.		
5	L	abs.	part	via Duct. Plex.	via ? Duct. Plex.	-	some brs.	high brs.	abs.	Very weak branches apparently crossed aorta to plexus from a plexus on the ant. surface of Innom. A. of noted source.	Linear plexus along the superior border of the Ductus Art. Preaortic part essentially a single branch.
	R	via R. Com. Tr.	?	-	-	-	via R. Com. Tr.	?	abs.		
6	L	part	? via Com. Tr.	? via Duct. Plex.	? via Duct. Plex.	-	part	-	abs.	Moderate sized branch source noted. Crosses Innom. A. obliquely to pass ant. to Aorta at origin of Innom.	Weak plexus with a simple trunk riding on upper border of Ductus to which it gives branches.
	R	?	? via Com. Tr.	?	-	via R. Com. Tr. ?	via R. Com. Tr. ?	-	-		
7	L	most	?	weak br.	via ? Duct. Plex.	-	all	-	-	poor specimen, blood infiltration- Very small branch arches over aorta at lat. angle formed by origin of Innom. A.	Heavy trunk along the superior border of the Ductus A. continuation of fairly complex Preaortic portion.
	R	-	? via small twig	-	-	-	-	-	-		
8	L	weak br.	? br. ant. Aorta	part	via ? Duct. Plex.	-	all	part	abs.	No contribution noted from the right	Somewhat linear and moderate sized Preaortic portion chiefly vagal, not particularly intimate with Ductus.
	R	-	-	-	-	-	-	-	-		
9*	L	most	-	? via Duct. Plex.	(?)	via SCC-SN?	most	-	abs.	The SCCSN on the rt. (with a contribution of X) passes ant. to bifurcation of Innom. follows lat. border to & crosses Aorta	Moderate sized plexus divisible into a med. and lateral portion. Strong communications with Ductus & Pulm. Tr.
	R	most	-	-	-	(?) via S-CCSN	-	-	abs.		
10	L	part	-	part	-	abs.	part	-	abs.	Strong contrib. with source noted, typical course as above, its br's directed mainly to rt. coronary plex.	Linear, moderate sized plexus with contributions to Ductus Art. Weak Preaortic portion except Br. from rt.
	R	most	? via br. to SCCSN	-	-	? via SCC-SN	via Com. Tr. ?	high br. ?	-		
11	L	part	(?) part	part	via Duct. Plex.	abs.	most	abs.	abs.	Moderate contrib. of rt., source noted, gives rise to br's to prox. part of Aorta. Passes near ganglion in upper part	Moderate sized linear plexus with brs. looping ductus and forming trunk on its inf. border. Ganglion in sup. part.
	R	? via Com Tr.	via Com. Tr.	? via Com. Tr.	-	-	def. br.	? via Com. Tr.	-		
12	L	-	-	part	via ? Duct. Plex.	-	part	all	abs.	Strong plexiform contrib. of the rt. supplying ant. surface of Aorta as well. Mainly Sym's.	Plexus essentially vagal fibers, weak communication with Ductus Art. Though between latter and Aorta, gap exists.
	R	? via Com. Tr.	? via Com. Tr.	? via Com. Tr.	-	-	? via Com. Tr.	-	-		
13	L	via Aort. Plex.	via Aort. Plex.	part	(?)	?	part	1br.	abs.	fair contrib. of the rt. splits and sends 1 br. down rt. side of Aorta with another br. the latter at orig. Innom. Artery	Weak plexus on sup. border of the Ductus (as if laterally placed) linear in structure. Ganglion in upper portion.
	R	abs.	via Com. Tr.	via Com. Tr.	-	abs.	? via br. to Tr.	-	-		
14	L	twig	twig	large group	via Duct. Plex.	? via SCC-SN	? via Sub. Plex.	abs.	abs.	A very small filament could be traced across Aorta from the rt. but source indeterminate. The ? mark indicate possibility	Preaortic N's ganglionic, appearing, pass into a strong linear plexus. Large Br. loops Ductus, yields Brs.
	R	-	-	?	-	-	?	-	-		
15	L	part	twig	weak brs.	via Duct. Plex.	abs.	main part	abs.	-	Moderate sized individual N. from rt. crossing Aorta at angle formed by origin of Innom. A. from that vessel.	Linear plexus with ganglion in upper part. Weak Preaortic. Brs. to medial aspect of Ductus. Brs. around Pulm. Tr.
	R	?	weak br.	?	-		?	-	-		

TABLE 8. DEEP CARDIAC PLEXUS

Dissection		Contributory Nerves								Description	Termination
		Sympathetic				Vagal					
No.	Side	Sup. Cerv. Card.n.	Mid. Cerv. Card.n.	Inf. Cerv. Card.n.	Thor. Card. N(s)	Sup. Cerv. Card.n.	Inf. Cerv. Card.n.	Rec. Card. N(s)	Thor. Card. N(s)		
1	L	-	most	part	part	-	abs.	abs.	all	center of plexus is post. to Aorta (arch & asc. portions) but ext. curvature of arch approx. limit, commun. with Sup. Plex.	splits into plexiform brs. ant. and post. to rt. Pulm. A. ant. brs. around Aorta to both Coron. Plex's post. brs. -to atrium
	R	abs.	all	all	all	abs.	all	abs.	all		
2	L	not rec.	not rec.	most	most	not rec.	not rec.	not rec.	not rec.	incompletely recorded somewhat more compact plexus seen, Thor. Sym. Card. brs. of both sides to rt. of esoph. to Deep P.	apparently musch the same as dissection #1
	R	not rec.	all	not rec.	all	not rec.	not rec.	not rec.	not rec.		
3	L	-	all	part	part	all (weak	part	abs.	abs.	diffuse plexus, esp. on rt. where brs. separate, most post. to Trans. Sin., commun. with Sup. Plexus, weak Thor. Sym's-lft.	most brs. post. to Trans. Sin., split around rt. Pulm. A., both to atria, brs. ant. to Sin. along Aorta to Coron. P's
	R	all	most	all	all	most	most	abs.	all		
4	L	all	all	part	(?) most	most	part	abs.	all	essentially a group of parallel strands most post. to Trans Sin., those on left commun. with Sup. P. & those on right direct	brs. post. to Trans. Sin. enfold Pulm. A. to atria, Br. to left of Sin. meet Sup. P. & extend to Coron. P. brs. ant. to Sin. -Coron.
	R	most	most	most	all	(?) all (weak)	part	abs.	all		
5	L	abs.	part	part	part	(?) via Sym.	-	abs.	(?) low br.	contrib. N's form plexus as they pass post. to arch, strong br. along Aorta, brs. post. to Pulm. A. are numerous, few ant.	brs. along Aorta to Coron. Plex's, few ant to Pulm. A. to base of Sup. V. C., brs. post. to Pulm. A. to area between Pulm. V's.
	R	most	part	all	all	(?) via Sym.	part	all	(?)		
6	L	-	part	part	part	(?) -	part	abs.	(?) most	N's pass mostly post. to Aortic Rec., mainly parallel & form a plexus on sup. bord. of rt. Pulm. A. which has a trans. arrang.	brs. passing ant. to Pulm. A. to Sup. V. C. at base, those post. to atria between Pulm. Vs, brs. left of Rec. to Coron. P's
	R	all	most	all	all	part	most	all	abs.		
7	L	-	most	most	part	-	-	most	abs.	N's essentially direct to sup. bord. rt. Pulm. A. to form plex. these brs. post. to Aortic Rec., brs. on left on post. of Aorta	brs. from rt. mainly post. to Aortic Rec. to atria as above, brs. from left mainly along post. aspect of Aorta-Coron. Plex's
	R	most	most	most	all	via Sym.	most	all	all		
8	L	most	most	part	part	most	-	abs.	-	1 large N. paralleled by several smaller passed post. to Aortic Rec. ant. to Pulm. A. (rt.) deviated left, other brs. typical	main br. passed to Coron. Plex's & post. aspect of atria between Pulm. V's, br. on rt. (X) to base Sup. V. C.
	R	most	all	all	all	all	all	all	all		
9	L	-	all	part	most	-	-	abs.	all	N's numerous but direct & can be traced individ., bear same relationships as above brs. of each side limited to it, mostly	same relat. to Aortic Rec. as above, brs. to rt. atrium at base of Sup. V. C., brs. of left & post. to Sin. to post. atria.
	R	-	all	all	all	-	all	abs.	all		
10	L	-	all	most	all	abs.	(?)	abs.	all	N's extend to sup. bord. of rt. Pulm. A. to there form a trans. arranged plex. post. to Aortic Rec., largely br. to left from rt.	brs. post. to Aortic Rec. with typical distribution, br. from rt. to left essentially along Aorta to Coron. Plex's, with lft. brs.
	R	(?) part	most	most	all	(?) via Sym.	most	all	all		
11	L	-	part	part	part	abs.	(?)	abs.	abs.	a series of parallel nerves upon tracheal bifurcation, most of these post. to Trans. Sin., commun. with Sup. Plex. to its left	3 main groups, 1 ant. to Trans. Sin. to atrium at base of V. C., 1 post. to Sin. between atria, 1 to left of Sin. -Coron. P's
	R	most	most	most	all	most via Sym.	part	most	all		
12	L	most	all	part	most	most via Sym.	-	abs.	-	main portion of Plex. ant. to left bronch. rather dense, most post. to Aortic Rec. br. of X on rt. direct to base Sup. V. C.	brs. ant. to Pulm. A. on rt. direct, on left split to enfold it, those ant. along Aorta those post. to post. aspect atria, Pulm. V.
	R	part	most	most	all	most via Sym.	most	all	all		
13	L	most	most	part	most	most via Sym.	part	abs.	part	more plexiform than others, brs. of rt. still direct but br. deviates to left & with left brs. forms dense plex. - Pulm. A.	brs. essentially as described above, those on left part of plex. essentially to left Coron. Plex. & post. atria between Pulm. V's
	R	abs.	all	most	all	abs.	part	all	all		
14	L	most	most	part	part	most	(?)	abs.	abs.	numerous commun. between component N's prior to formation of trans. plex. post. to Aort. Rec. & sup. to rt. Pulm. A.	strong brs. ant. to Pulm. A. on rt. to base Sup. V. C., brs. on left ant. to Pulm. A. pass along Pulm. Tr. to lft. Coron. Plex., brs. to atria
	R	-	all	most	all	-	all	all	all		
15	L	most	most	most	part	abs.	-	-	abs.	1 large N. of rt. to ant. aspect of left bronchus at sup. bord. of rt. Pulm. A. where it is joined by brs. of left, other	some brs. ant. to Rec. along post. aspect of Aorta, others post. to Rec. to sup. bord. of rt. Pulm. A., to term's as noted above
	R	most	most	most	all	-	part	all	all		

9. INNERVATION OF THE DUCTUS ARTERIOSUS

Dissect. No.	Source Of Contributory Nerves						Description	
	Sympathetic Nerves				Vagal Nerves		Size & Distribution	Communi-cations
	Superior Cerv. Cardiac	Middle Cerv. Cardiac	InferiorCerv. Cardiac	Thoracic Cardiac	Cervical Cardiac	Thoracic Cardiac		
1	(?) Via Sup. Plex.	(?) Via Sup. Plex.	1 Br. direct from I. C. G.	1 br. TG3, 1 br. TG4, 1 br. TG2 with 1 br. of IGT2-3	(?) Via Sup. Plex.	1 br. of Left Rec.	Moderate extends along Pulm. Tr.	Sup. Plex. and Aortic Plexus
2	(?) Via Sup. Plex.	(?) Via Sup. Plex.	br. to X leaves again to ductus	None	(?) Via Sup. Plex.	(?) Left Rec.	Weak and indefinite plexus	with Sup. Plex.
3	None	None	Br. along subclav. art. (Sub. Plex. ?)	(?) Via Aortic plexus	(?) Via Sup. Plex.	Tiny Twig from left Rec.	Well defined plexus (I. C. C. S. N.	with Sup. Plex.
4	Via Common N. (M. C. C. S. N. C. C. N. of X)	Via Common Nerve	Via twig or Sup. Plex.	Via. collat. T. trunk (T2, 3 and 4	Via Common Nerve	(?)	3 parts, 1 common n. on sup., T. n. inf. I. C. C. S. N.	Sup. Plex. and collat. T. trunk
5	Not present per se	(?) Via Sup. Plex.	Via Br. of Sub. Plex.	2 twigs via plexus of brs. from TG1, 2, 3&4	Via Sup. Plex.	Tiny Twig from Cardiac N. of Vagus	moderate sized plex. mainly I. C. C. S. N. (Sub. Plex.)	Intimate Sup. Plex. connect.
6	Br. from plexus ant. to subclav. art.	None (?)	Via Sub. plex. and br. to thoracic plexus	brs. of upper 3 T. Gang. form plexus, brs. to ductus	(?) Via Sub. Plex. with S. C. C. S. N.	None	Well defined, extends on pulm. trunk	Sup. Plex.
7	large Br. Via Sup. Plex.	None	Via twig from Sub. Plex. and br. to T. card. n's.	Upper 3 T. C. N.'s via plexus with br. I. C. C. S. N.	(?) Via Sup. Plex.	2 small brs. of Left Rec.	Poor specimen Plexus infiltrated with blood	--
8	None	None	Via well defined Sub. Plex.	Twigs from 2nd and 3rd Thor. G.	Via Sub. Plex. or Sup. Plex.	1 br. of Vagus	Primarily 1 N. of Sub. Plex. with Br.'s Pulm. Tr.	(?) Sup. Plex. and Aor. Plex.
9	(?) Via Sup. Plex.	(?) Via Sup. Plex.	2 Brs. well defined of Sub. Plex. This N.	(?) Fair sized N's from TG2 and 3	2 brs. loop ductus part of Sup. Plex.	None	Fair sized with loop of Vagal N's, source identified	communi-cations slight
10	Via Common N. with all possible elements	None (?) slight communi-cation with others	Via common N. from weak Sub. Plex.	None (T. N's weak)	Via. br. unites with S. C. C. S. N.	Twig from left Rec.	1 Br. loops Ductus Yields brs., 1 br. to dist. end of duct.	Sup. Plex.
11	Slight if any	Slight br. from N. looping Ductus	1 Br. from Sub. Plex. 1 br. joins Thor. contrib.	1 Br. from Collat. tr. formed by TG brs. 2, 3 and 4.	(?) Via Sup. Plex.	None	Essentially 2-3 brs. extends to Pulm. Tr.	few com-munica. make source ob-vious
12	None	None	2 Brs. from Sub. Plex. (1 Br. loops Ductus)	Weak br. of collat. tr. made of brs. of ICG & TG2	Via Sup. Plex.	Via Sup. Plex. left Rec. (?)	Essentially 1 large N. descends on Ductus & Pulm. Tr.	Sup. Plex. (nearly all vagal)
13	(?) Via Sup. Plex.	(?) Weak br. via Sub. Plex.	1 large Br. 1 small br. from Sub. Plex.	Fine brs. Collat. tr. formed by br. of ICG & TG1, 2&3	None (see br. of X in thorax)	1 Br. of X in thorax splits to enclose & supply duct	Mainly 1 br. along left side, give twigs to Pulm. Tr.	Sup. Plex.
14	None (?)	None (?)	2 large Brs. 2 small brs from Sub. Plex.	1-2 brs. of collat. tr. of T. S. N.'s	Via twig to sub. Plex.	Twig from left Rec.	Extensive 3-4 brs. of Sub. Plex. 1-2 brs. of Collat. Tr.	Sup. Plex. and Collat. tr. of T. S. N.'s
15	None (?)	None	1 twig from Sub. Plex. and twig via anom. left S. V. C.	Derived via collat. tr. formed by brs. of TG1, 2&3	Via Sup. Plex.	Twig from Vagus as it X's	Marked with nerve along inf. border essentially TG brs.	Sup. Plex. Collat. tr. of T. S. N.'s

VITA

The candidate was born in Salt Lake City, Utah on May 19, 1925. He attended the public schools of that city and graduate from South High School in June of 1943. He then enrolled at the University of Utah and graduated from that institution, gaining a Bachelor of Science degree, in June 1947. The candidate then entered graduate work in the Department of Anatomy, School of Medicine of the University of Utah. In August, 1949 he was awarded a Master of Science degree, having written on the neurocytological and electrophysiological effects of Metrazol and ethyl alcohol on the albino rat. He entered the graduate school of Louisiana State University in September, 1949, working in the Department of Anatomy of the Medical School.

EXAMINATION AND THESIS REPORT

Candidate: Frank D. Allan

Major Field: Anatomy

Title of Thesis: Innervation of the Heart and the Ductus Arteriosus and Other Features of the Autonomic Nervous System of the Full Term Human Fetus.

Approved:

Charles M. Goss
Major Professor and Chairman

Richard J. Russell
Dean of the Graduate School

EXAMINING COMMITTEE:

A. Sidney Harris

Louis A. Toth

George Nelson Ronstrom MD

Frank N. Low

Ruth A. Miller

George W. Hamlett

Blanche Jackson

Date of Examination:

May 12, 1954